# A MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT BASED ON A STATISTICAL ANALYSIS OF SPECTROMETRIC DATA

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*A report of research performed under*
*NASA Grant NGR/05-003-080 for the*
National Aeronautics and Space Administration
Office of Space Sciences and Applications

*by personnel of the*
SCHOOL OF FORESTRY, UNIVERSITY OF CALIFORNIA

*Final Report* *30 June, 1965*

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I. INTRODUCTION

In recent years it has been demonstrated that certain kinds of information sought by scientists through the medium of remote aerial reconnaissance are best obtained when sensing in one particular region of the electromagnetic spectrum; other kinds, in some other region. It follows that a greater amount of information will be obtainable if two or more sensors are used, each especially adapted to the sensing of energy in its own spectral band, than if reliance were to be placed on either of the sensors alone. Most of these sensing devices provide a photograph directly, but some record the energy in some intermediate form which is then reconstituted into a photo-like image. The terms "spectrozonal photography", "multispectral photography", and "multiband spectral reconnaissance" have been employed by various experts to describe this concept.

The brightness, or tone, with which an object is registered on a photograph depends largely on the amount of light which the object reflects within the spectral zone employed in taking the photograph. Two or more objects may reflect exactly the same amount of energy in one spectral zone; if so, the photo interpreter cannot differentiate them on the basis of tone when all available photos of the objects have been taken only in that zone. It is very unlikely, however, that the objects will reflect exactly the same amount of energy in <u>all</u> spectral zones for which there is a remote sensing capability. Consequently, if the objects are photographed in two or more <u>properly-selected</u> spectral zones, it should be possible to differentiate them; furthermore, it may be fully as informative, in some instances, to know that the objects have the same reflectance characteristics in one spectral zone as to know that they have different reflectance characteristics in a second spectral zone. Alternately stated, a more complete "tone signature" can be read from photographs taken in two or more zones than from photographs taken in only one zone, and the more complete the tone signature, the more certain the identification.

Generally speaking, the higher the altitude from which photography is taken, the greater the reliance which a photo interpreter must place on an object's tone signature when attempting to identify it, and the less reliance he can place on the object's configuration. Since the multispectral tone signature of a rock, soil or vegetation type often indicates the composition of that type, tone signatures assume considerable importance for the interpretation of natural terrain features.

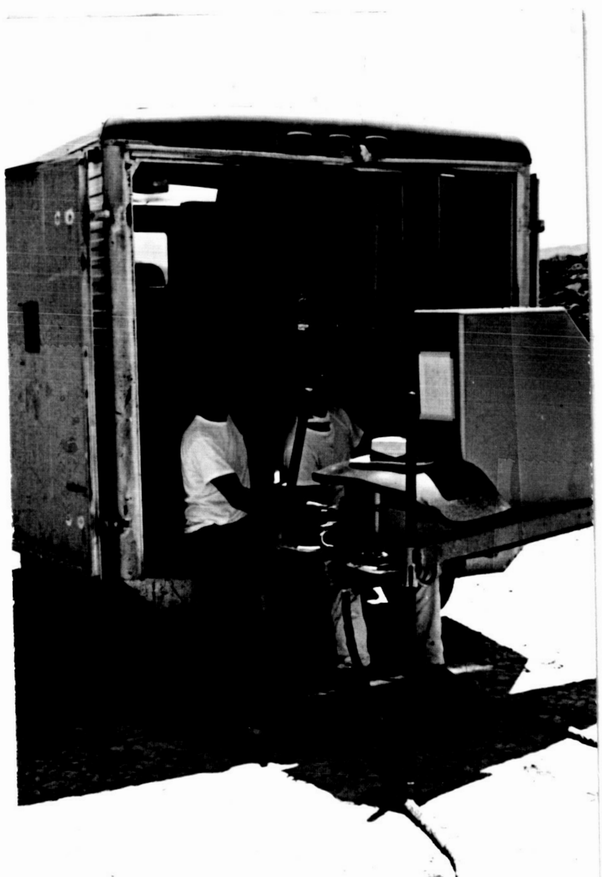
From the foregoing it is apparent that, before adequate interpretation can be made of airborne and spaceborne photography, it is important to secure the spectral responses of the terrain features that are to be identified. Pursuant to this principle, the primary objectives of the experiment herein reported were: (1) to define the spectral reflectance characteristics of selected terrain features in a specified test area by on-the-ground measurements of spectral reflectance, (2) to determine from an analysis of spectrometric data the optimum film-filter combinations that should be used when taking multispectral photography of these features; and (3) to predict the tone signatures of the terrain features as they would appear on such photography. For test sites having a significant vegetative cover, an additional objective was (4) to correlate the seasonal changes in light reflectance from the vegetation with the tone values of that vegetation on multispectral photography taken at the various seasons. It was recognized that the satisfying of these objectives would necessitate considerable correlation of both ground observations and spectral reflectance measurements with the geologic and vegetative interpretation of the multispectral photographs.

Most of this experiment dealt with the Pisgah Crater area in the Mojave Desert of California. In this arid region, the seasonal effects of vegetation are not of primary importance. Hence, little consideration was given to objective (4) when studying the Pisgah Crater area. However, as an extension of the studies reported herein similar tests are now being made on a selected site in the San Joaquin Valley of California, in which seasonal effects of vegetation assume paramount importance. The results of these studies will be reported subsequently.

## II. EXPERIMENTAL PROCEDURE

1. Aerial photographs were obtained from the U.S. Geological Survey, Washington, D.C., of the test site wherein this investigation was to be conducted, namely the Pisgah Crater Area in the Mojave Desert of California.
2. Within the general test site, boundaries of two test strips were delineated directly on the photos. One of these strips was centered directly over Pisgah Crater itself; the other strip sampled representative terrain conditions at one edge of the Pisgah lava flow in the vicinity of a dry lake bed known as "Lavic Lake".
3. A detailed on-the-ground study of the two test strips was made by the principal investigator in conjunction with two expert geologists of the California Division of Mines and Geology, both of whom had acquired several years of experience in mapping the geology of the Mojave Desert and environs. The result of this study was a delineation of what are presently believed to be the most significant terrain classes of the Pisgah Crater test site, as illustrated in the stereo triplets on the following two pages.
4. On the basis of this study, and while still in the field, a large number of representative sample plots were selected for each terrain class, and each was plotted on the aerial photographs.
5. Through use of a random selection process, a determination was made, for each terrain class, as to which of these representative plots would be used when obtaining spectrometric data and target-array samples.

Spectrophotometer in operation on a sample plot in rough lava.



Spectrophotometer readings are automatically recorded in graph form in the instrument trailer.

6. At the request of the principal investigator, NASA entered into a separate contract with the Barrier Intrusion Branch, Engineer Research and Development Laboratories, Army Corps of Engineers. Under this contract, Army personnel, using their portable spectrophotometer, occupied each of the selected spots for the purpose of making at least nine light reflectance measurements within each terrain class. In each instance the spot at which light reflectance measurements were taken (within one of the randomly selected plots) was as indicated by the principal investigator and his assistants. A total of 100 readings were thus made of light reflectance from the terrain, wavelength-by-wavelength, for the entire range within which the spectrophotometer is operative (approximately 260 to 2,000 millimicrons). A full report relative to this E.R.D.L. effort is to be found in a publication entitled "Reflectance studies of Pisgah Crater, California" by Harold Throckmorten, L. B. Matthews, and J. R. Smirnov, of the U.S. Army Engineer Research and Development Laboratories, Fort Belvoir, Virginia (Aug. 1964). The equipment used in making these reflectance studies is illustrated on the following page.

7. From each spot at which light reflectance measurements had been made, a sample of the weathered surface material was obtained and transported to the Electrical Engineering Laboratory of the University of California at Richmond, California. Most of the surface samples were no more than about two to four inches square, but were of ample size to permit their being analyzed with the laboratory-type spectrophotometer. In several instances, however, much larger samples were obtained for later use in photographic tests to be made from

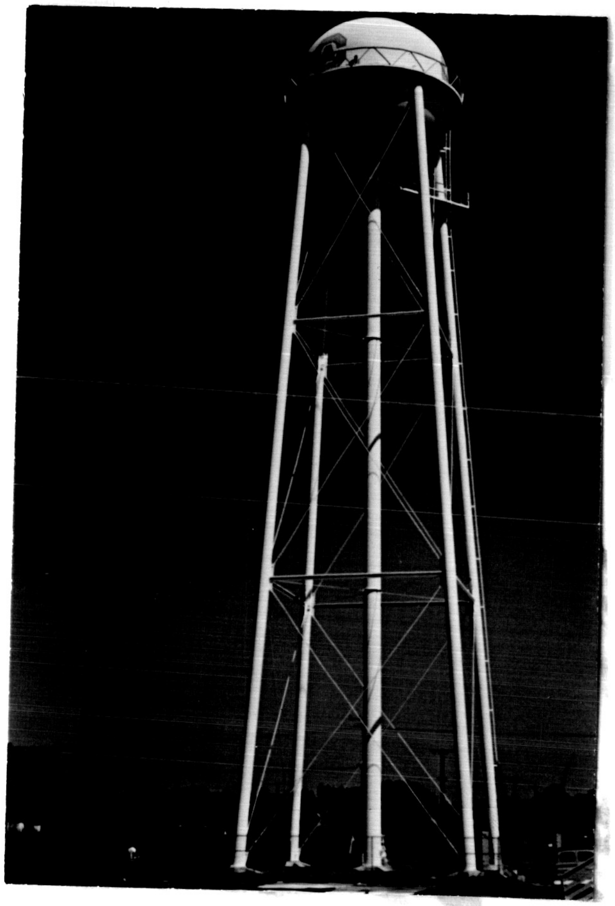
a water tower on the Davis Campus of the University of California and also from Glacier Point in Yosemite Valley, as later described.

8. From each sample a representative portion was mounted with its weathered surface exposed; its spectral reflectance characteristics were then measured, wavelength-by-wavelength, with a General Electric laboratory spectrophotometer, throughout the entire range for which that spectrophotometer is operative (400 to 1,000 millimicrons). Although this instrument has a more limited spectral range than the E.R.D.L., portable spectrophotometer, it nonetheless covers virtually all of the spectrum in which photographic images can be obtained directly on film emulsions by means of remote reconnaissance; hence it gave information highly pertinent to the present study. A major objective in obtaining this second set of readings was to determine the extent to which reliance might be placed in future tests on <u>laboratory</u> measurements of light reflectance, rather than on more costly and laborious <u>field</u> measurements.

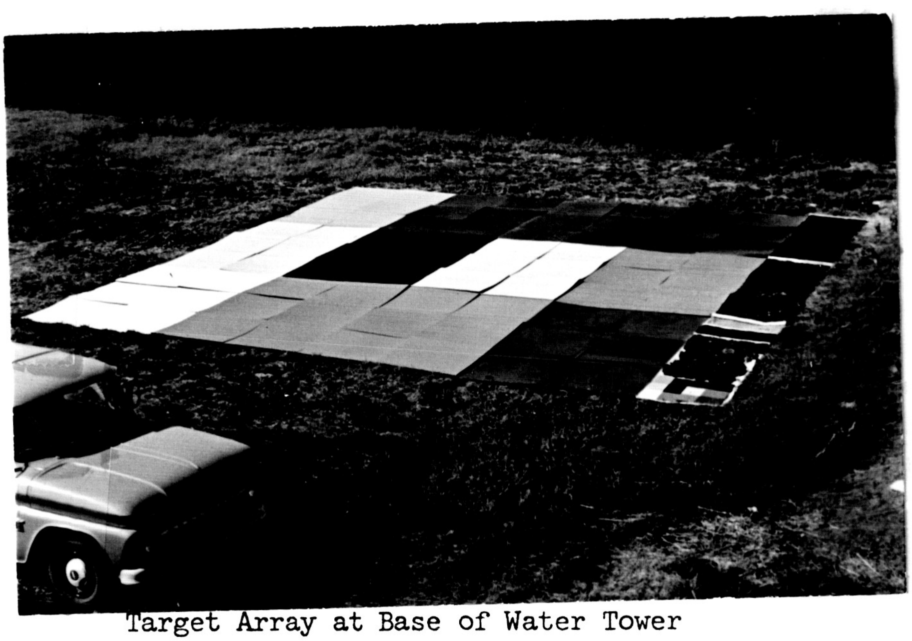
9. The remainder of each of the samples for which a <u>large</u> amount of material had been selected was transported to a spot beneath a 150-foot water tower on the Davis Campus of the University of California.

10. A total of 72 color panels made of Masonite sheets, each four feet square and sprayed with paints having proper hue, value and chroma characteristics (as recommended by Harry J. Keegan of the Colorimetry Laboratory, National Bureau of Standards, Washington, D.C.) also were transported to the Davis Campus.

11. Sections 4 x 5 inches in size were cut from rolls of each of the following kinds of aerial film: Aerial Ektachrome film, Camouflage

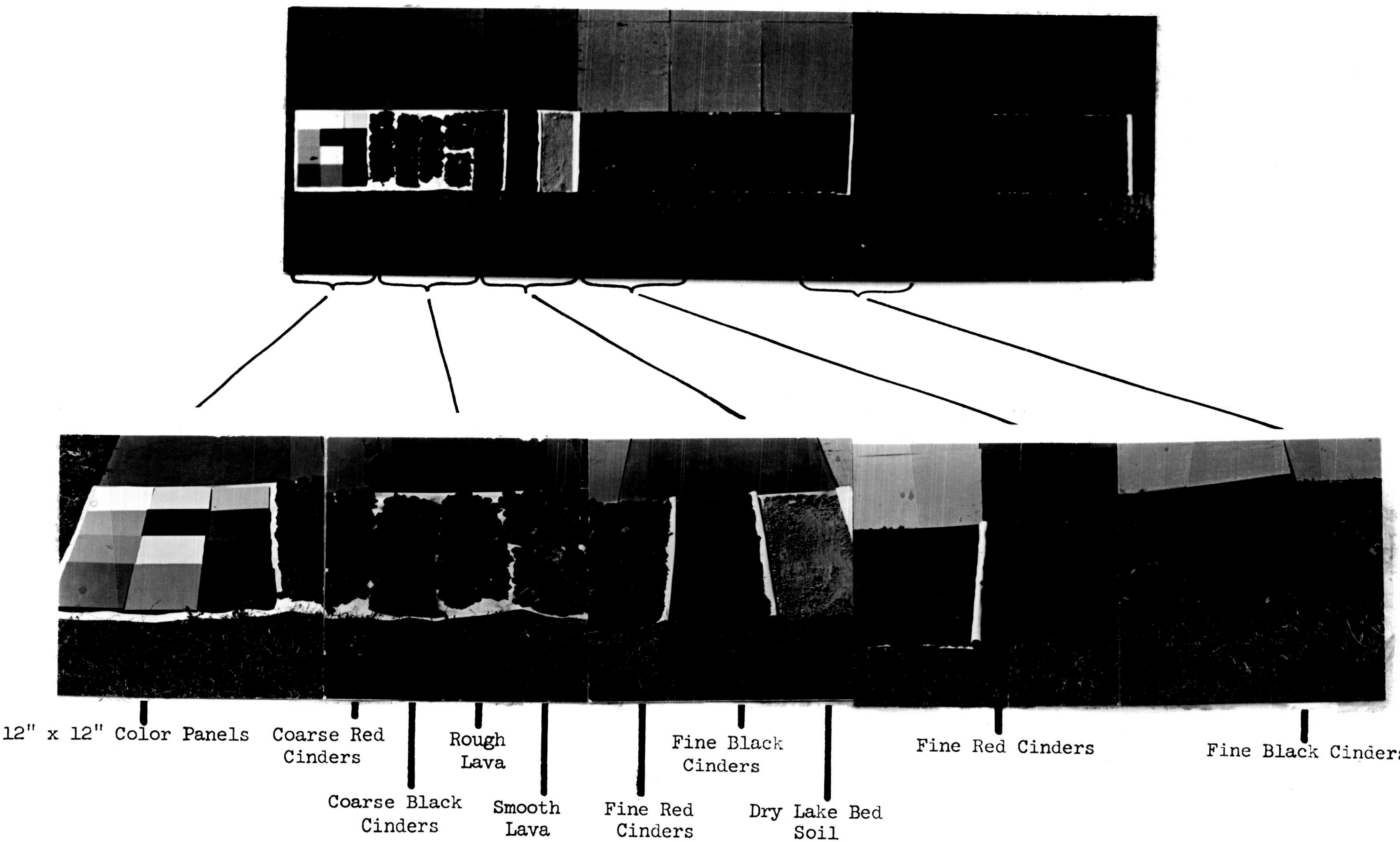


Water Tower, Davis, California.
Catwalk is approximately 150 feet above the ground. Note color panels at base of tower.



Target Array at Base of Water Tower

TARGET ARRAY
PISGAH CRATER TERRAIN SAMPLES



Detection film, Aerial Panchromatic Super XX film, and Infrared Aerographic film. In addition, 4 x 5 inch sheets were purchased of each of the following kinds of film that normally are used in taking conventional terrestrial photography: Orthochromatic, Tri-X Panchromatic, Infrared, Ektachrome, and Ektacolor. A large assortment of narrow-band and wide-band filters also was obtained, including the Wratten 12, 25A, 47B, 61, 87C and 89B. The cut films were mounted in holders and exposed, using a Speed Graphic camera, in combination with various filters. The target for these exposures consisted of the color panels and Pisgah Crater terrain samples. The camera station was the catwalk of the 150-foot water tower at Davis, beneath which the target array had been emplaced. One set of photos was taken at a high sun angle, the photographic period being centered around high noon, local sun time; a second set of photos was taken at a low sun angle, centered about the one hour period immediately preceding sunset on the same day. All of the photos were truly vertical and were taken from precisely the same camera station. A few additional photos were taken with a second Speed Graphic camera to determine the extent to which possible differences in lens optics might affect the tone or color values with which the various elements of the target array registered on the photographs.

12. Upon completion of the Davis test, materials comprising the target array were transported to a point on the floor of Yosemite Valley, which is approximately 3,000 feet lower than the selected camera station at Glacier Point. The slant range to the target array from the

camera station was about 4,000 feet. Consequently near vertical aerial photos could be taken which were in many respects comparable to those taken at Davis. The main difference was that a much longer column of air (4,000 feet instead of 150 feet), with correspondingly larger amounts of atmospheric haze, separated camera station from target in the Yosemite test as compared with the Davis test. Both high and low sun angle photos were taken at Yosemite, just as at Davis. Color temperature readings at the times of photography also were taken both at Yosemite and Davis.

13. All of the Davis and Yosemite photography was processed and printed promptly to avoid possible deterioration of the image (particularly of the color films).

14. Using a Welch Densichron with a 0.02" aperture, the tonal densities were read for each element of the target array as imaged on each of the Davis and Yosemite negatives.

15. From a preliminary analysis of the Pisgah Crater spectrophotometric data, several black-and-white film-filter combinations were selected which appeared to offer greatest promise of providing, either individually or in concert, unique tone signatures for the various Pisgah Crater terrain classes.

16. Using a K-17 camera having a focal length of 12 inches, true aerial photographs were taken of the two selected test strips at Pisgah Crater, with each of the selected film-filter combinations; aerial photography of the same areas also was flown on the same day, with both Aerial Ektachrome film and Camouflage Detection film. For each film-filter combination, both high and low sun angle photography was taken, and color temperature readings were taken as they had been at

Yosemite and Davis. The flight altitude was approximately 4,000 feet above the rim of Pisgah Crater. The same color panels as had been used at both Davis and Yosemite were included in a target array that was emplaced on the rim of Pisgah Crater on the day of photography.

17. Using the Welch Densichron, tone density values were read for each terrain class and for each element of the color panel array on each of the aerial negatives that were obtained in the flights over Pisgah Crater.

18. Using all of the spectrometric data obtained with the portable and laboratory spectrophotometers, and using the procedures and computer techniques described in detail in the original proposal, a complete spectrometric analysis was made with the IBM 7094 computer at Berkeley. From this analysis it was possible to compute the theoretical tone value with which each kind of material comprising the target array should register on each of the multispectral photographs taken at Davis, Yosemite and Pisgah Crater. These computations also incorporated accurate information on spectral sensitivities of the films used, spectral transmissivities of the filters, and color temperature of the illuminant at the time of photography.

## III. ANALYSIS OF DATA

The analysis of the raw spectrophotometer curves and densitometer measurements of negative density was divided into two distinct phases: (1) the prediction of the film-filter combination, or combinations, which would b est exploit the reflectance differences between two or more objects of interest; and (2) the prediction of tone values for the objects of interest as seen on the optimum film-filter combinations thus specified.

A. Prediction of optimum film-filter combinations. In Appendix A of the original proposal for this research, the techniques employed to predict optimum film-filter combinations by Electronic Data Processing (E.D.P.) techniques were outlined. Briefly stated, the system attempts to: (1) assess the variability of reflectance associated with each terrain type or other object of interest throughout the visible and near-infrared portion of the electromagnetic spectrum; (2) calculate the normalized mean reflectance difference, and the standard deviation of the normalized mean reflectance difference; (3) apply a "T" test to determine the significance of the reflectance differences; and (4) predict the part, or parts, of the visible and near-infrared portion of the electromagnetic spectrum wherein significant reflectance differences exist between objects of interest.

The data for this portion of the analysis consisted of nine reflectance curves for each terrain type selected for study at the Pisgah Crater test site. (In each instance the nine curves came from three blocks with three random samples taken in each block.) The reflectance characteristics of the samples were measured by both the U.S. Army's E.R.D.L. portable spectrophotometer and a General Electric laboratory spectrophotometer, as previously described. In addition, three reflectance curves were obtained of each color panel from the G. E. laboratory spectrophotometer.

A computer program was written to calculate the normalized mean reflectance differences between all possible combinations of color panels and of terrain types, and to assess the significance of these differences. After completion of the computer program, however, it became necessary to forego temporarily the prediction of the film-filter combinations which would best exploit the significant reflectance differences between terrain types at Pisgah Crater. This decision was necessitated by the unfortunate theft of the E.R.D.L. spectrophotometer truck and generator. The equipment was eventually recovered and the readings completed; however, this unexpected event forced postponement to a later date the reading of reflectance characteristics of many of the terrain types at Pisgah Crater. Although this postponement effectively ruled out the making of predictions of optimum film-filter combinations, it in no way invalidated the making of a subsequent determination of how effectively such predictions might be made. Hence the basic objective for this part of the study was nonetheless achieved.

With the aid of such spectrometric data as had been obtained before theft of the E.R.D.L. truck and generator, a decision was made to photograph the Pisgah Crater test area with six film-filter combinations which collectively would sample each major spectral band throughout that portion of the electromagnetic spectrum being considered in this study (0.4-1.0 microns). These film-filter combinations were:

(1) Panchromatic film -- Wratten 12 Filter (.48-.72 microns)

(2) Panchromatic film -- Wratten 47B Filter (.33-.49 microns)

(3) Panchromatic film -- Wratten 61 Filter (.47-.62 microns)

(4) Panchromatic film -- Wratten 90 Filter (.56-.72 microns)

(5) Infrared film -- Wratten 89B Filter (.71-.96 microns)

(6) Infrared film -- Wratten 87C Filter (.8-.97 microns)

B. Prediction of tone values on multispectral photography. The prediction of tone values by the use of Electronic Data Processing techniques is somewhat more difficult than that of predicting optimum film-filter combinations. The reflectance curves of the object of interest must be combined with the film sensitivity and filter transmission curves such that the final value obtained from the computer program is predictably related to the actual tone value of the object as seen on an aerial negative. To provide this information, a computer program was written which would perform the following functions: (1) average the reflectance curves obtained from the spectrophotometers used in this study (including a limited number of readings obtained with a Cary laboratory spectrophotometer and a Pritchard portable spectrophotometer) thereby providing curves for each terrain type and color panel which represented the mean of all variability within that type; (2) integrate the reflectance curves of the objects of interest with the film sensitivity curves and the filter transmission curves for the film-filter combinations used in the study; (3) standardize the values from (2) on a zero to 100 scale using those values exhibiting the greatest difference as the standards (e.g., white and black color panels, Lake Bed Material and Rough Lava, etc.); (4) standardize the density values obtained from the aerial negatives in the same manner; (5) predict, using two separate functions (linear and logarithmic) a theoretical tone value for each object of interest as seen on a specified film-filter combination; (6) compute the following: (a) the coefficient of correlation between the actual and predicted tone values; (b) the Kolmogorov-Smirnov statistic1/ for the same two values, and (c) the least square regression line between these two values.

From a study of the statistics obtained in step (6), conclusions could be made as to the value of making a statistical analysis to derive film-filter specifications. In this regard each of the following were to be carefully examined: (a) the relative merits of portable and laboratory spectrophotometers, (b) the effect of length of air column between camera and target, and consequent atmospheric attenuation, (c) the effect of exposure, (d) the effect of sun angle, (e) the effect of camera angle, (f) the effect of slope and aspect, (g) the effect of disturbance of the terrain materials and (h) the relative merits of the E.D.P. prediction procedure and other alternate procedures.

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1/ The K-S statistic, frequently used to test "goodness of fit" of frequency distributions, is used in this study to provide an indication of the magnitude of deviation between the actual and the predicted tone values.

## IV. RESULTS OF THE ANALYSIS

A. Advantages and limitations of the various spectrophotometers used in the study. Four spectrophotometers were used in the study, including a U.S. Army E.R.D.L. portable spectrophotometer, a General Electric laboratory spectrophotometer, a Pritchard portable spectrophotometer and a Cary laboratory spectrophotometer (the latter two were limited to estimating the reflectance characteristics of a selected number of color panels). The following discussion is pertinent to the advantages and limitations of the spectrophotometers used.

### Pritchard Portable Spectrophotometer

Developed by the Itek Corporation of Palo Alto, this spectrophotometer has the advantage of true mobility, being relatively light and battery operated. It appears that the instrument can be quite useful for obtaining an appreciation of the reflectance characteristics between objects in the visible portion of the electromagnetic spectrum. Its use in multispectral research is limited, however, by at least two factors: (1) its inability to record continuously across the spectrum thereby necessitating interpolation of the reflectance curve's true shape and (2) the limited spectral range in which the instrument, as presently constructed, is capable of being used to measure light reflectances (400-650 millimicrons in this test). This latter deficiency limited effective use of the instrument for predicting tone values to only one film-filter combination -- Panchromatic film with a Wratten 61 filter. For all other film-filter combinations used the spectral range of the reflectance readings did not coincide sufficiently well with the spectral bands used in forming the photographic image.

## Cary Laboratory Spectrophotometer

The Cary spectrophotometer, a high precision instrument, is capable of giving accurate readings of one reflectance characteristic of desired samples. The main limitation of this spectrophotometer, like that of the Pritchard, is the limited range in which it provides measurements of light reflectance (400-850 millimicrons in this test). Although useful for predicting optimum film-filter combinations in the visible portion of the spectrum, this instrument was not useful for predicting tone values or optimum film-filter combinations in much of the near infrared portion of the spectrum. The film sensitivity and filter transmission exceeded the range of the reflectance readings of the instrument.

## General Electric Laboratory Spectrophotometer

This spectrophotometer was found to be more useful than the Cary due to its capability of recording reflectance characteristics of desired objects over a greater spectral range (400-1000 millimicrons). The tone values on practically all of the film-filter combinations used in the study could be predicted by use of this instrument. This spectrophotometer could not be used, however, to predict tone values when using film-filter combinations that had sensitivity below 400 millimicrons.

U.S. Army's E.R.D.L. Portable Spectrophotometer

The E.R.D.L. spectrophotometer was the most versatile of the four instruments tested in this study. The instrument was capable of recording reflectance characteristics continuously from 320 millimicrons to 2100 millimicrons; hence, it did not exhibit the limitation in range of readings that were inherent to the other three machines. In addition, this spectrophotometer had the capability of reading samples in their undisturbed state. The instrument might not be considered by some to be truly portable, however, since its use is restricted to areas where a four-wheel vehicle can traverse to within 30 to 40 feet of the area to be studied.

B. Laboratory vs. portable spectrophotometers. As stated previously, one of the objectives of this study was to evaluate the relative merits of obtaining reflectance measurements from undisturbed samples in the field by the use of portable spectrophotometers (e.g. the E.R.D.L. portable spectrophotometer), with that of obtaining spectral reflectance from disturbed samples transported from the field to a remotely situated laboratory spectrophotometer (e.g. the General Electric laboratory spectrophotometer).

An examination of the coefficients of correlation of the predicted and actual tone values[1/] for terrain samples at Pisgah Crater indicates that both field and laboratory spectrophotometers provide acceptable predictions of tone values. In practically all cases, however, the coefficients of correlation between predicted and actual tone values obtained by use of

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1/ The coefficients of correlation referred to in this paper are those calculated between the predicted tone values obtained by the use of the logarithmic prediction function and the actual tone values measured from the negative.

the E.R.D.L. portable spectrophotometer were higher than those obtained by use of the General Electric laboratory spectrophotometer. In addition, the reflectance characteristic of two terrain types, Desert Pavement and Alluvium, could be obtained only by use of the E.R.D.L. spectrophotometer, since these materials could not be transported to the laboratory intact.

The data suggest the following general conclusions: (1) the General Electric laboratory spectrophotometer can effectively be used to provide the reflectance characteristics necessary for the prediction of optimum film-filter combinations and tone values for color panels. (2) The General Electric laboratory spectrophotometer is somewhat less useful for estimating the reflectance characteristics of terrain types due to the difficulty of transporting heterogeneous samples intact to the instrument. Acceptable results were obtained in this experiment, however, for those terrain classes which were relatively homogeneous in nature, such as Lake Bed Material, Smooth (Pahoehoe) Lava, and Red Fine Cinders. (3) The E.R.D.L. portable spectrophotometer provides a number of advantages over the General Electric laboratory spectrophotometer, including the ability to record the reflectance characteristics of heterogeneous samples; and the capability of recording a greater portion of the electromagnetic spectrum. The cost of operation of this machine is considerably greater, however, than that of comparable laboratory machines; hence its use should be limited to situations where laboratory specimens cannot be prepared or where a greater range of reflectance measurement is desired.

A precise and meaningful cost comparison is difficult to make from the experiments reported herein. However, some indication of costs is to be found in the fact that the average costs per spectrometric curve under the conditions of these experiments was approximately $100 for the E.R.D.L. portable spectrophotometer and $5 for the G. E. laboratory spectrophotometer.

C. Effect of exposure, processing, and type of camera. In the system used for this report to predict tone values, the following assumption was initially made concerning the multispectral negatives used as controls: photographic exposure, processing, and variability in camera shutter speed all have a constant, linear effect on negative density. This effect, therefore, is assumed to cause merely a shift of the gamma curves, or a shift on the linear part of the gamma curve of the negative and thus is adjusted during the standardization of the density values. Since the tone values measured from negatives were used as controls to which the predicted tone values were compared, it appeared important to test this assumption of constant linear variation.

Three tests were performed at the Davis water tower to assess the effect of the variables: (1) a bracketing experiment was performed to define the limits of the constant, linear variation due to exposure, (2) replications were performed with the same camera by giving each of a series of negatives the same exposure but submitting them for processing at different times in order to define the variation due to processing, and (3) a second camera of the same type was used to obtain simultaneous photographs at the same exposure, to define the variation due to differences in cameras.

The analysis indicates that the assumption of constant linearity was valid with respect to processing and to the use of another camera of obtaining the multispectral photography used in the analysis. Each platform was associated with a different haze condition and length of air column.

In a simplified sense the effect of atmosphere on the tone values obtained in this study of multispectral photography can be grouped into three broad categories: (1) no effect, (2) constant linear variation, and (3) other forms of variation. The present E.D.P. system for prediction of tone values will correct the effect of (1) and (2) through the standardization procedure employed. The effect of (3) will not be given proper weight, however, by the present standardizing procedure; hence large variations between the coefficients of correlation for the different areas could be expected.

An analysis of the color panel data provides the following observations: (1) the coefficient of correlation for a particular film-filter combination is uniformly high for all camera stations (and associated air column lengths). Therefore, an assumption can be made that the effect of atmosphere is predictable by the present system (i.e., either there was no effect, or there was a constant linear effect), and (2) examination of the results of the K-S test for photographic negatives having optimum exposure from the three areas also shows no significant variation due to atmosphere; hence, if a linear variation is occurring, it is correctly adjusted by the standardization procedure described earlier in this report.

The data indicate, therefore, that for the multispectral photography obtained from the three remotely situated platforms used in this study, there was little or no significant effect of atmosphere on the ability to predict tone values on the multispectral photography. This is the same type. There was, however, a significant deviation between the predicted and actual tone values due to changes in exposure. This suggests that the effect of exposure was not acting in a constant, linear fashion when the exposure was more than about 1.5 f stops away from the optimum. The presence of high coefficients of correlation indicates that the effect is nevertheless linear in nature and that the effect of poor exposure on negative density can be assumed to be proportional. Further examination of the negatives indicated that the large number of significant values for the K-S test was not due to difficulties in the prediction system, but rather to the difficulty in obtaining the quality of negatives that the system requires.

This variation in negative quality has little effect on the system's ability to predict optimum film-filter combinations, however, as evidenced by the high coefficients of correlation between the predicted and actual tone values. Moreover, since the effect of poor exposure appears to be of a proportional linear nature, the variation can be corrected, once the negative is obtained, by fitting a least square regression line to the actual and predicted values, and then correcting the predicted tone values with the regression line.

D. Effect of distance from target (length of air column). The tone values obtained when sensing electromagnetic radiations on Earth from a platform remotely situated from the target of interest depend in part on the extent to which the intervening atmosphere attenuates the radiated energy. In order to investigate the effect of this variable, three remotely situated platforms were used, as previously described, when not to say that there is no effect of atmosphere but rather that the effect can be corrected by the prediction system.

E. Effect of color temperature of the illuminant. Color temperature was carefully measured at each of the three areas at the time of photography, using a General Electric color temperature meter. By the use of the same sequence of considerations listed above, a general conclusion can be drawn from the statistical analysis regarding the effect of this variable. The data indicate that there was no significant effect of color temperature of the target illuminant on the ability to predict tone values on the multispectral photography obtained in this experiment.

F. Effect of sun angle. Since the angle at which incident radiation strikes the target logically might produce significant variation in actual tone values obtained on aerial negatives, an attempt was made to evaluate the effect of this variable.

The Pisgah Crater terrain classes exhibited the following characteristics, and hence did not provide an acceptable control for this portion of the study: (1) some of the terrain types present had different slopes, aspects, and particle sizes and (2) for those terrain types with uniform slope (essentially flat) and uniform particle size, it was not known how the composition might be altered in transport to a spectrophotometer or to a remotely situated target array, such as was constructed at Davis and Yosemite.

The color panel target array, however, provided an acceptable control due to its uniform surface and reflectance characteristics, and, when placed on a flat surface, eliminated difficulties due to variations in slope and aspect. The color panels provided an additional advantage in that they could be moved between areas of interest without introducing an effect due to disturbance.

The color panel array, constructed under the Davis water tower and below Glacier Point at Yosemite National Park, permitted study of the effect of sun angle by allowing a large number of multispectral photographs to be obtained over a short period of time. The same color panels were photographed on the rim of Pisgah Crater, at two sun angles, to test the effect of this variable on tone values as imaged on true aerial photography.

Comparison of the high and low sun angle data presented in this report shows the following: sun angle, by affecting the brightness with which the scene is illuminated, exerts an effect on absolute tone values in the various spectral bands. However, for both the high and low sun angle photographs, there are high coefficients of correlation between the tone values predicted and those obtained for the color panel array at the three areas. In addition, for those negatives of optimum exposure, the K-S test shows no significant difference between the predicted and actual tone values for the same film-filter combination at the two sun angles tested. Therefore, the general conclusion can be drawn that variation due to changes in sun angle is correctly adjusted by the E.D.P. system and did not significantly affect the ability to predict the tone values on the multispectral photography studied.

G. Effect of camera angle. Although not directly involved in this study, two experiments were carried out in cooperation with GIMRADA personnel to attempt to evaluate the effect of camera angle to the target on resultant tone values. In both tests, the color panels used at Davis, Yosemite, and Pisgah Crater, were used as the control in order to determine the effect of this variable. One of the tests involved the use of the Houston-based NASA Convair 240A aircraft, while the other utilized the Davis water tower with the color panels displayed below.

A general conclusion of these two tests is as follows: as seen from the camera station, the angle between the target and the optical axis does not affect significantly the tone values of the color panels on the multispectral photography obtained. It can be inferred, therefore, that camera angle had no significant effect on the ability to predict tone values on the multispectral photography obtained in this study.

H. Effect of slope and aspect. In the two previous sections, the effect of sun angle and camera angle were evaluated for color panel data, while keeping slope and aspect constant. Although no detailed study was carried out designed to isolate the effect of slope and aspect, some general impressions can be obtained using the same photography, but focusing attention on the terrain types at Pisgah Crater. It can be assumed that since the coefficients of correlation for color panels on this photography are high, a reduction in the coefficients of correlation when predicting tone values for terrain types would reflect the variation introduced by slope, and aspect. This reduction does indeed occur, indicating that non-linear variation does effect the tone values on the negative.

Examination of the individual predicted and actual tone values on those negatives which have optimum exposure further indicates that certain terrain types, such as Red Fine Cinders, Desert Pavement, Lake Bed Material, Smooth Lava and Rough Lava, normally do not exhibit significant differences between actual and predicted tone values. Coarse Black and Coarse Red Cinders do exhibit large differences, and their tone values vary significantly with a change in sun angle. Referring to the stereo triplets on pages 8 and 9, it is apparent that the terrain types showing minimum deviation between predicted and actual tone values are those which have a relatively flat slope. It is also apparent that those terrain types which exhibit large deviations are normally on steep slopes and, in the case of Coarse Red and Coarse Black Cinders, are on a slope which was in shade during the low sun angle photography. These observations suggest that an assumption of constant linear variation does not appear to be valid when applied to aspect and slope. It is probable, however, that the variation due to these factors can be predicted with the proper standardizing procedure and prediction function.

In this regard, a separate study investigating the effect of slope and aspect on color panel tone values is presently being analyzed and the results will be reported at a later date.

I. Effect of disturbance on target array tone values. A great deal of effort was expended during the duration of this study to transport terrain samples from the Pisgah Crater area to Davis and Yosemite National Park. These samples were incorporated in a target array which was photographed using a number of spectral bands. One intent of this portion of the study was to determine whether samples of natural terrain features (when collected and transported to more favorable vantage points, reconstructed, and photographed) exhibited gross changes in tone value when disturbed. If the tone values did not exhibit non-predictable differences, then certain difficulties, such as the effect of slope, aspect, and texture could be examined with a degree of control not possible in the natural situation.

The data indicate that the actual tone values of the disturbed target array do deviate significantly from the predicted tone values, but in a manner that can be predicted, as evidenced by the high coefficients of correlation between these values.[1/] The large computed K-S values for negatives with optimum exposure indicate that the variation introduced by the disturbance of the natural terrain class occurs in a linear fashion, but not in a constant manner. An examination of the individually paired tone values indicates that those terrain types that are relatively homogeneous, such as Fine Black Cinders, Lake Bed Material, and Fine Red Cinders, exhibit the least deviation between actual and predicted tone values. This suggests that in future studies, the use of special target arrays may provide the necessary control for the evaluation of variations due to slope, aspect, and texture.

<u>J. Relative merits of E.D.P. prediction of optimum-film-filter combination and alternate systems</u>. As stated in an earlier section, the E.D.P. system attempts to determine the largest and most significant contrast differences between objects of interest continuously across the portion of the spectrum desired and to evaluate and predict film-filter

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1/ The correlation analysis, in this case, is weakened somewhat by the small number of observations of the sample.

combinations that will exploit these differences.

A number of alternate systems for obtaining optimum film-filter combinations have been suggested and some are in use. The most frequently used is the multi-camera, or multi-lens camera system. In this system six to nine film-filter combinations are chosen, normally bracketing the visible and near-infrared portion of the spectrum, and an evaluation made on aerial photography flown with this system as to the relative merits of these film-filters for identifying, by tone characteristics, the objects of interest.

It is apparent that both systems have advantages and disadvantages, of which a few of the more important are:

## E.D.P. Film-Filter Prediction

Advantages:

(1) Provides a knowledge of reflectance characteristics continuously across the spectrum which allows a choice of film-filters to be flown which may have a very narrow or broad band width, depending on the statistically significant differences that are present.

(2) Allows the evaluation of new films, different types of filters, and other alterations of the sensor, without time consuming trials necessary to obtain usable imagery (such as tests of exposure, focusing, or in some instances, the actual development of the new, specially sensitized film).

Disadvantages:

(1) This is an indirect method (i.e., light reflectance of samples of the objects of interest must be read by the spectrophotometer, with

consequent uncertainties [as analyzed in this report] of the applicability of such readings in predicting photographic tone values).

## Multi-Camera Prediction

Advantages:

(1) Provides a general impression of the change in relative tone values of the objects of interest for the portion of the spectrum photographed, allowing the viewer to choose that part, or parts, of the spectrum photographed which is most useful.

(2) Does not require the spectral analysis of samples in order to select the film-filter combinations to be used in the camera (i.e., it is a more direct method).

Disadvantages:

(1) In most cases the film-filters used in the system have such a broad spectral range that the probability of choosing the optimum film-filter combination that will exploit the reflectance differences between objects (which in some cases may be as small as 10-20 millimicrons and which may exhibit reversals in tone between large spectral band widths) is very small.

(2) This system does not eliminate ground evaluation. Although significantly different tone signatures appear on the photograph, it is still necessary to determine what they represent.

The above discussion indicates that the optimum system for the choice of film-filter combinations which will exploit differences in reflectance between objects is perhaps a combination of both approaches discussed above. The prediction of optimum film-filters by E.D.P. techniques is just one step in obtaining usable information about terrain types, for acceptable photography must be obtained within the spectral bands desired. A multi-camera or multi-lens system is ideally suited for this task due to its ability to obtain multispectral photographs at the same instant in time and the same orientation in space. As a corollary, more efficient use of the multi-camera systems could be made if it were known before the aerial photo flight occurred what film-filter combinations would best exploit the differences between the objects desired. This determination is best made by the analysis of spectrometric data.

## V . CONCLUSIONS

The results of this study have indicated that optimum film-filter combinations can be selected by the statistical analysis of spectrometric data. The analysis has also indicated that for many objects of interest, the standardized tone value that will be obtained from an aerial negative can be predicted before the photograph is taken.

The following factors were found to have no significant effect on the ability to predict optimum film-filter combinations, and on the ability to predict tone values for the color panels and terrain types used in this study: (1) distance from target to camera, (2) sun angle, (3) camera angle, (4) variability in processing of film, and (5) camera variability.

The factors listed below were found to have no significant effect on the ability to predict optimum film-filter combinations, but had a significant effect on the ability to predict the standardized tone value of the objects of interest in the study: (1) exposure, (2) disturbance of terrain samples, and (3) slope and aspect.

The results of this study suggest that more efficient use might be made of the multi-camera or multi-lens systems currently used to obtain multispectral photography if an analysis of the spectral reflectance characteristics of objects of interest in the fundamental test sites is performed. This analysis should, in most cases, allow the research scientist to choose the necessary optimum film-filter combinations prior to the flight mission.

# APPENDIX

Note: It was considered inappropriate to include in this report a detailed explanation of the statistical methods employed in making the calculations. Nevertheless the following facts are considered essential to interpretation of the tabular data:

(1) The data are tabulated under both linear and logarithmic headings to demonstrate, through comparison of corresponding correlation coefficients,that the relation between predicted and actual tone values tends to be curvilinear rather than linear.

(2) The "predicted tone values" were obtained by statistical analysis of spectrometric data as described in the body of this report.

(3) The "actual tone values" are density values as read directly on the original negatives with a Welsh Densichron instrument.

(4) The "calculated tone values" were obtained by use of a least square regression line, fitted to the predicted and actual tone values.

(5) The appearance in the tables of an occasional negative tone value results from the assumption that the black panel (or, for terrain samples, the rough lava) would photograph darkest of all elements of the target array in each spectral band, and could therefore be assigned a tone value of "0". Although in some bands this was not true, the occurrence of negative tone values did not complicate or invalidate the statistical analysis.

(6) The "computed K-S Maximum" expresses the deviation between the predicted and actual tone values, in one instance, and between the calculated and actual tone values in the other, as indicated in the table.

(7) The "K-S Statistic" defines the limit of the confidence interval at a 95% confidence level.

(8) The "coefficient of correlation" refers to the relationship between the predicted and actual tone values. The reader is reminded that high correlation coefficients between these values can be obtained (as in many of the following examples) even though the two values are not numerically the same or even similar. This apparent contradiction is explained by the fact that the predicted and actual tone values may be highly correlated without having the same absolute magnitude. In this regard the K-S Statistic provides an indication of the deviation, in an absolute sense, between the predicted and actual tone values.

(9) The appendix which follows includes only representative examples of the photography obtained with various film-filter combinations.

## VII. ACKNOWLEDGMENTS

Presentation of the material contained in this report has been made possible through the cooperative effort of several individuals and organizations. Among the students and staff of the School of Forestry at the University of California who rendered vital services in the collection of ground truth, compilation of data, and analysis of data used in this report were Jerry Lent, Tom Tracy and Glen Miller.

Grateful acknowledgment also is given to Phil Langley and Dave Sharpnack of the Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service, Berkeley, for their valuable assistance in the development of the computer programs used in this study.

Finally, acknowledgment is given to the personnel of Cartwright Aerial Surveys, Incorporated, who flew the aerial photography to precise specifications, thereby allowing valid estimates to be made from the photo images.

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

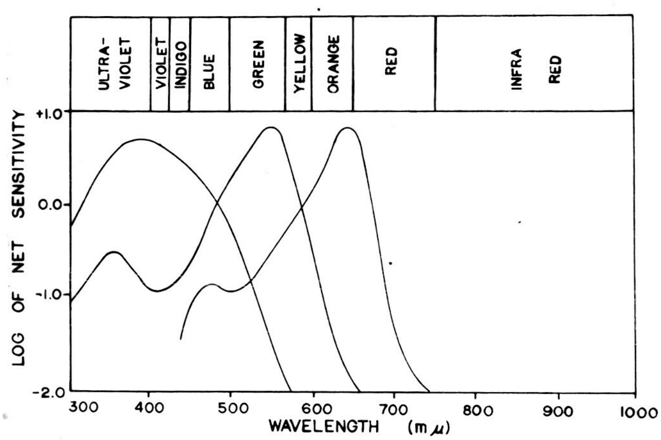
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

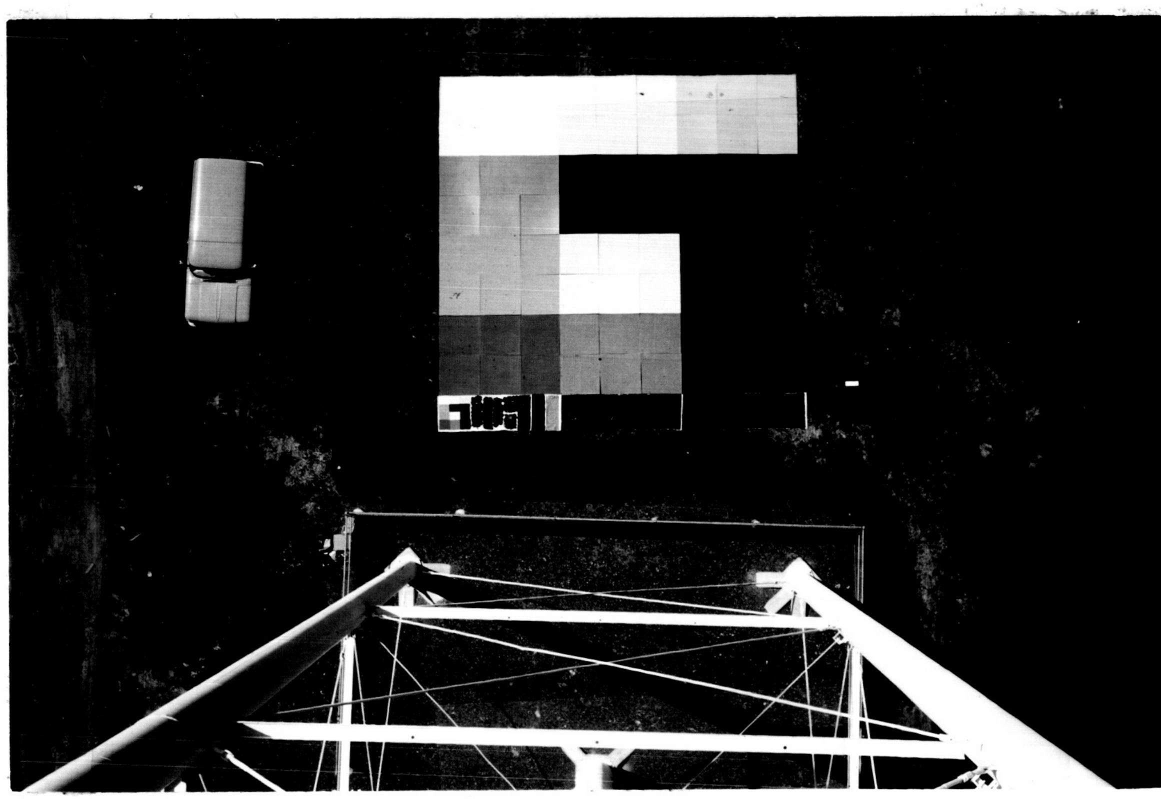
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175°K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY



Film: Ektachrome Filter: None Sun Angle: High

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

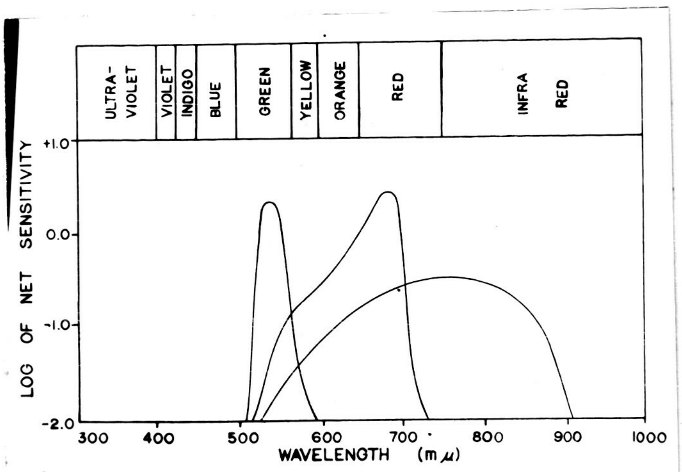
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

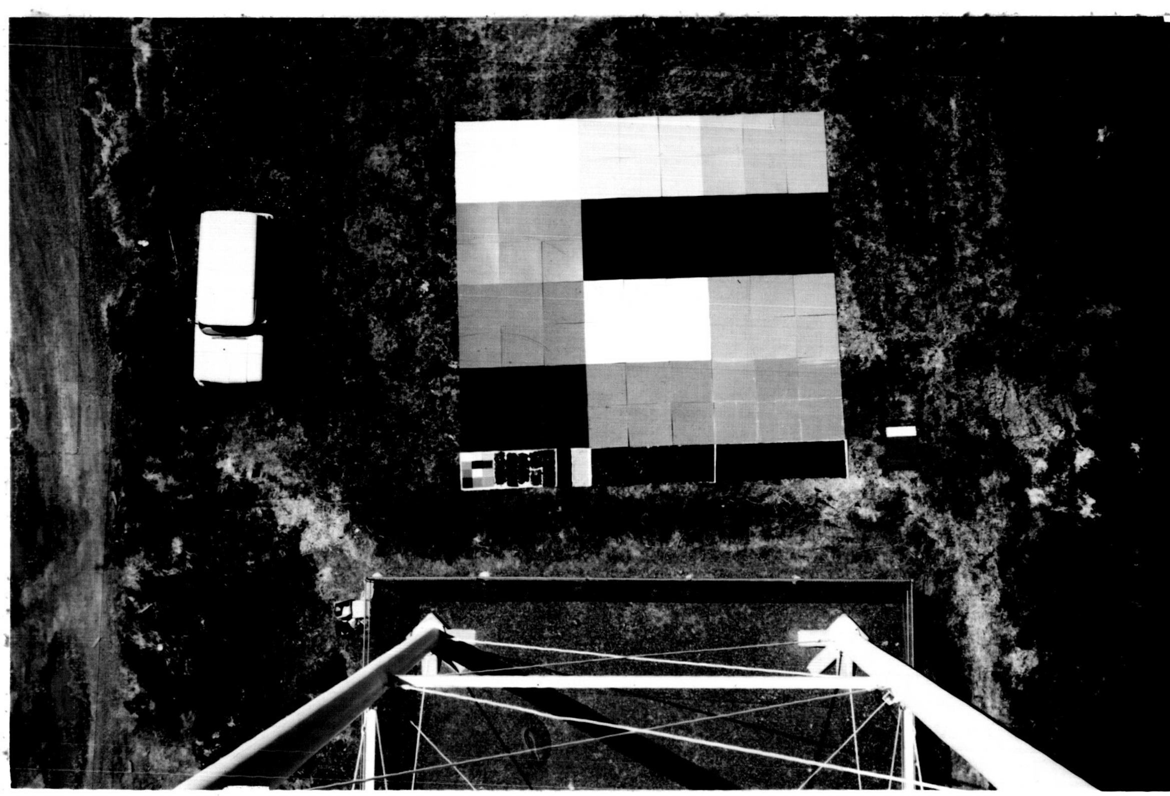
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14) | | |

TARGET ARRAY



Film: Camouflage Detection Filter: Wratten 12+EF-2200 Sun Angle: High

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

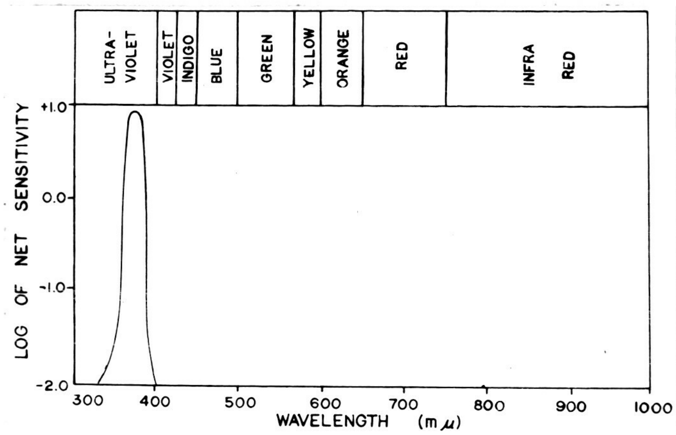
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

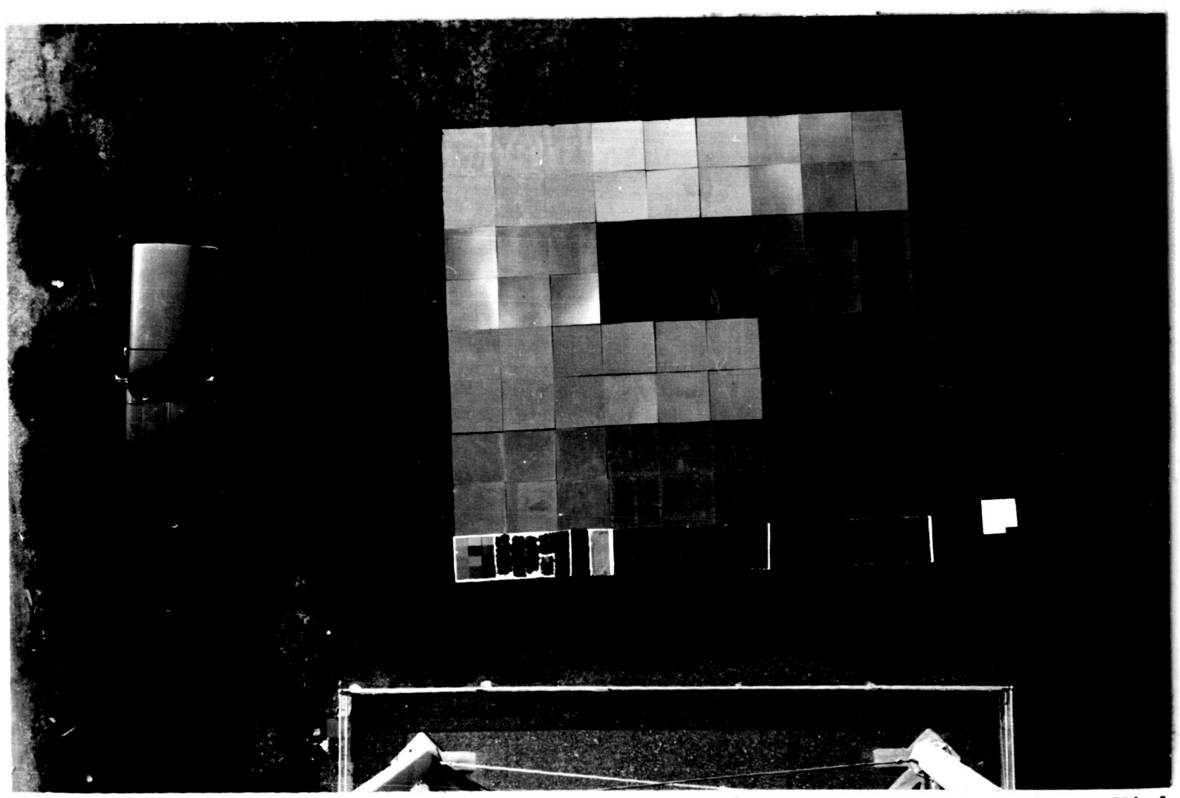
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY



Film: Orthochromatic Filter: Wratten 18A Sun Angle: High

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

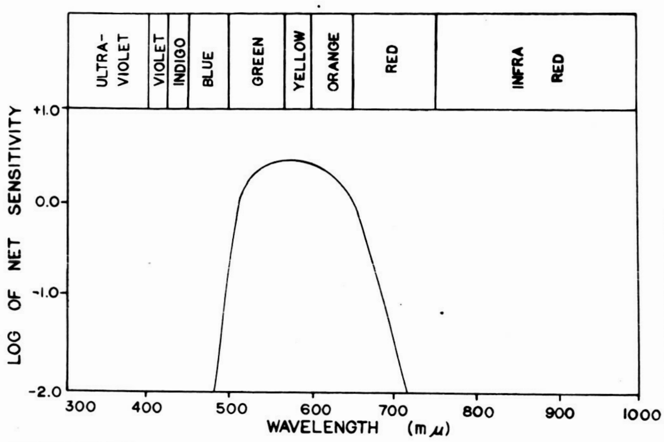
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

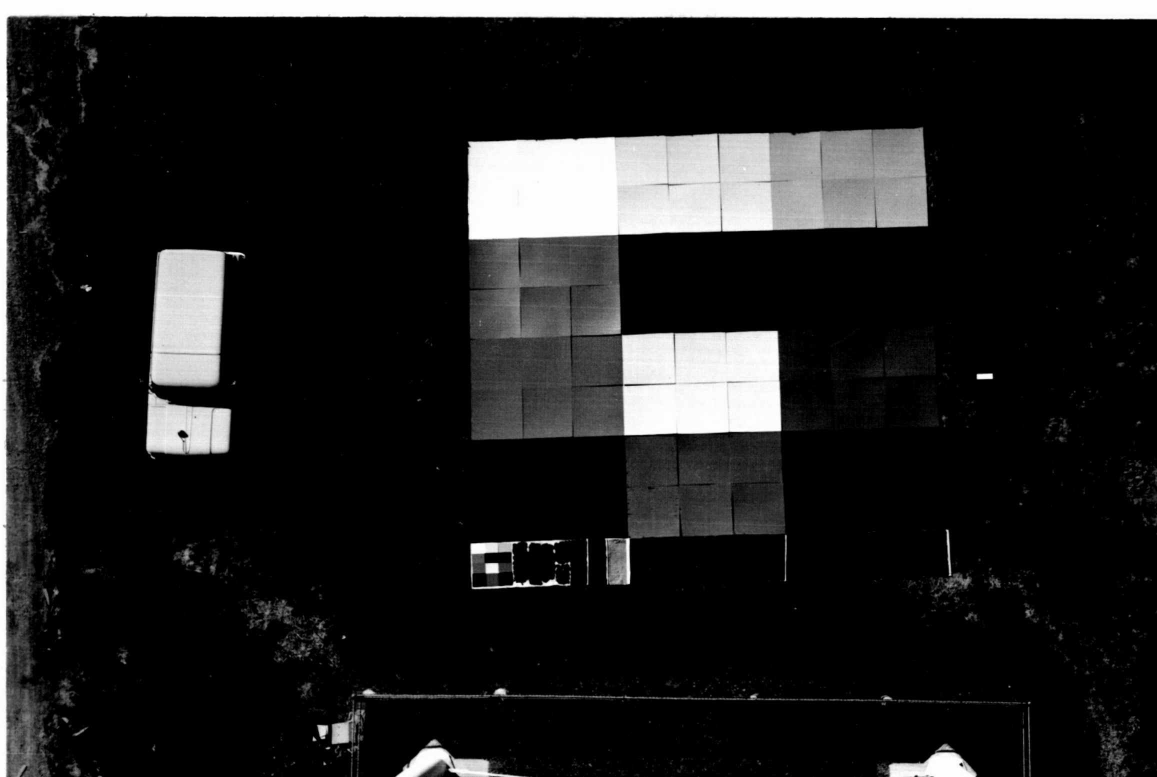
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY



**Film:** Panchromatic (Tri-X) **Filter:** Wratten 12 **Sun Angle:** High

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 12

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 120 | 100 | 100 | 110 |
| Light Grey | 54 | 97 | 89 | 87 | 97 | 97 |
| Medium Grey | 36 | 89 | 76 | 78 | 89 | 88 |
| Dark Grey | 21 | 81 | 66 | 66 | 81 | 76 |
| Brown | 6 | 51 | 56 | 39 | 51 | 50 |
| Green | 17 | 81 | 63 | 62 | 81 | 72 |
| Yellow | 65 | 98 | 96 | 91 | 98 | 100 |
| Rust | 20 | 73 | 65 | 65 | 73 | 75 |
| Blue | 5 | 56 | 55 | 35 | 56 | 46 |
| Chartreuse | 15 | 79 | 62 | 59 | 79 | 69 |
| Red | 15 | 58 | 62 | 59 | 58 | 69 |
| Black | 0 | 0 | 52 | 0 | 0 | 11 |
| Computed K-S Maximum | 1.438* | 0.070* | | 0.167* | 0.014 | |
| K-S Statistic | 0.072 | 0.046 | | 0.050 | 0.046 | |
| Coefficient of Correlation | | 0.72 | | | 0.96 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 12

Sun Angle: High

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 106 | 100 | 100 | 82 |
| Red | 13 | 0 | 28 | 56 | 0 | 40 |
| Rust | 23 | 40 | 37 | 68 | 40 | 52 |
| Chartreuse | 17 | 53 | 32 | 62 | 53 | 45 |
| Green | 19 | 60 | 34 | 64 | 60 | 48 |
| Blue | 0 | 0 | 17 | 0 | 0 | -14 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.471* | 0.178* | 0.276* | 0.092* |
| K-S Statistic | 0.104 | 0.086 | 0.073 | 0.081 |
| Coefficient of Correlation | 0.83 | | 0.82 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 12

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 105 | 100 | 100 | 93 |
| Black Fine Cinders | 0 | -1 | 14 | -1 | 0 | -3 |
| Red Coarse Cinders | 9 | 39 | 23 | 39 | 48 | 43 |
| Red Fine Cinders | 20 | 51 | 33 | 51 | 65 | 59 |
| Rough Lava | 0 | 0 | 14 | 0 | 0 | -3 |
| Computed K-S Maximum | 0.465* | 0.157* | | 0.112* | 0.036 | |
| K-S Statistic | 0.120 | 0.099 | | 0.093 | 0.096 | |
| Coefficient of Correlation | | 0.92 | | | 0.99 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 12

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 105 | 100 | 100 | 92 |
| Black Fine Cinders | 2 | -1 | 15 | 15 | -1 | 7 |
| Red Fine Cinders | 25 | 51 | 36 | 70 | 51 | 62 |
| Red Coarse Cinders | 8 | 39 | 20 | 45 | 39 | 37 |
| Rough Lava | 0 | 0 | 13 | 0 | 0 | -9 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.400* | 0.152* | 0.179* | 0.042 |
| K-S Statistic | 0.117 | 0.099 | 0.090 | 0.095 |
| Coefficient of Correlation | 0.92 | | 0.98 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

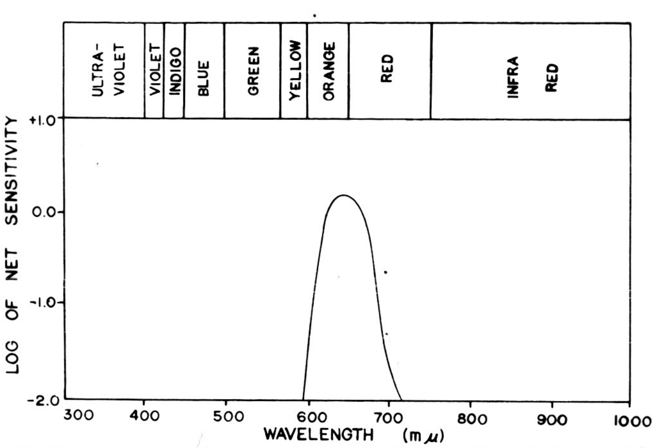
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

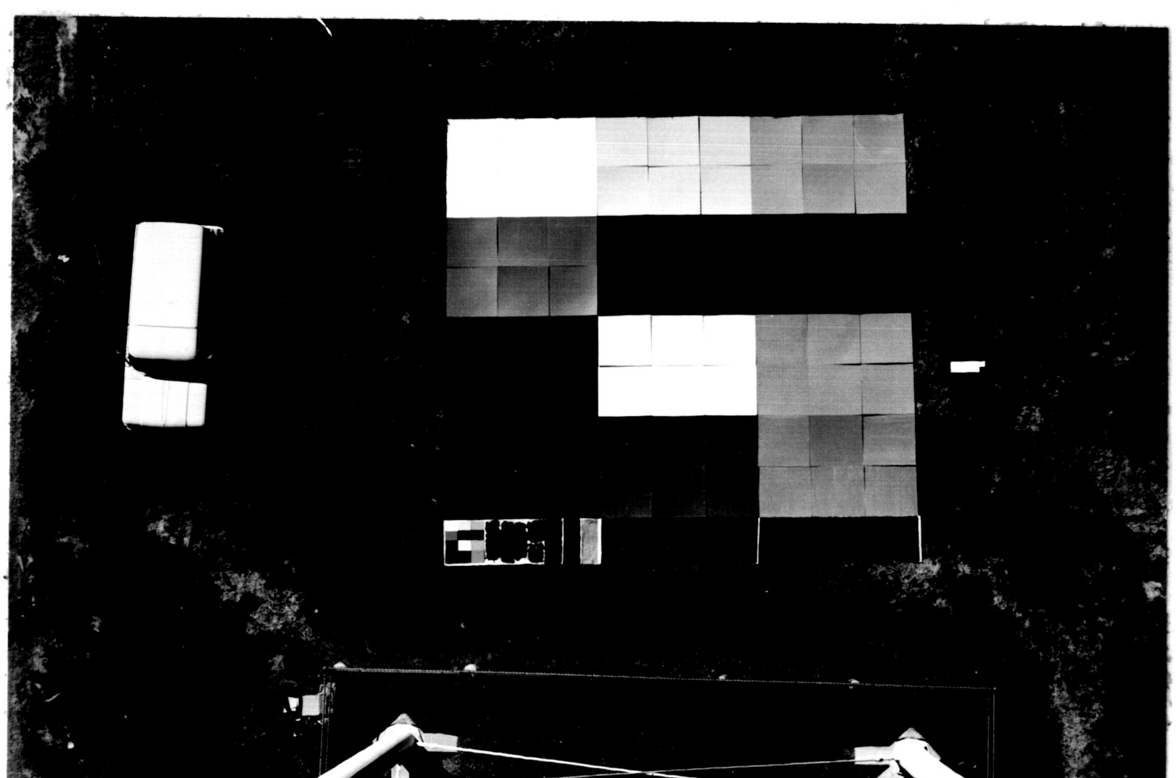
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY



**Film:** Panchromatic (Tri-X) **Filter:** Wratten 25A **Sun Angle:** High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 25A

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 120 | 100 | 100 | 109 |
| Light Grey | 53 | 96 | 88 | 86 | 96 | 96 |
| Medium Grey | 35 | 90 | 76 | 77 | 90 | 88 |
| Dark Grey | 20 | 82 | 66 | 65 | 82 | 77 |
| Brown | 8 | 61 | 58 | 45 | 61 | 58 |
| Green | 8 | 67 | 58 | 45 | 67 | 58 |
| Yellow | 73 | 99 | 102 | 93 | 99 | 103 |
| Rust | 36 | 89 | 77 | 78 | 89 | 88 |
| Blue | 3 | 46 | 54 | 24 | 46 | 38 |
| Chartreuse | 12 | 73 | 60 | 54 | 73 | 66 |
| Red | 37 | 84 | 77 | 78 | 84 | 89 |
| Black | 0 | 0 | 52 | 0 | 0 | 16 |
| Computed K-S Maximum | 1.304* | 0.068* | | 0.189* | 0.020 | |
| K-S Statistic | 0.069 | 0.046 | | 0.050 | 0.046 | |
| Coefficient of Correlation | | 0.73 | | | 0.97 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 25A

Sun Angle: High

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 110 | 100 | 100 | 97 |
| Red | 45 | 73 | 68 | 83 | 73 | 81 |
| Rust | 45 | 82 | 68 | 83 | 82 | 81 |
| Chartreuse | 13 | 50 | 44 | 56 | 50 | 56 |
| Green | 7 | 59 | 39 | 42 | 59 | 44 |
| Blue | 0 | 0 | 34 | 0 | 0 | 5 |
| Computed K-S Maximum | 0.733* | 0.093* | | 0.046 | 0.029 | |
| K-S Statistic | 0.094 | 0.071 | | 0.071 | 0.071 | |
| Coefficient of Correlation | | 0.83 | | | 0.97 | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 25A

Sun Angle: High

Spectrophotometer: General Eelctric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 105 | 100 | 100 | 82 |
| Black Fine Cinders | -2 | -10 | 2 | -15 | -10 | -18 |
| Red Coarse Cinders | 10 | 14 | 14 | 50 | 14 | 39 |
| Red Fine Cinders | 21 | 46 | 25 | 66 | 46 | 53 |
| Rough Lava | 0 | 0 | 4 | 0 | 0 | -5 |
| Computed K-S Maximum | 0.156* | | 0.108 | 0.221* | | 0.091 |
| K-S Statistic | 0.118 | | 0.111 | 0.089 | | 0.097 |
| Coefficient of Correlation | | 0.96 | | | 0.93 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 25A

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 104 | 100 | 100 | 82 |
| Black Fine Cinders | 2 | -10 | 3 | 15 | -10 | -3 |
| Red Fine Cinders | 29 | 46 | 31 | 73 | 46 | 55 |
| Red Coarse Cinders | 11 | 14 | 12 | 52 | 14 | 34 |
| Rough Lava | 0 | 0 | 0 | 0 | 0 | -18 |
| Computed K-S Maximum | 0.084 | | 0.087 | 0.376* | | 0.094 |
| K-S Statistic | 0.114 | | 0.110 | 0.088 | | 0.098 |
| Coefficient of Correlation | | 0.97 | | | 0.92 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

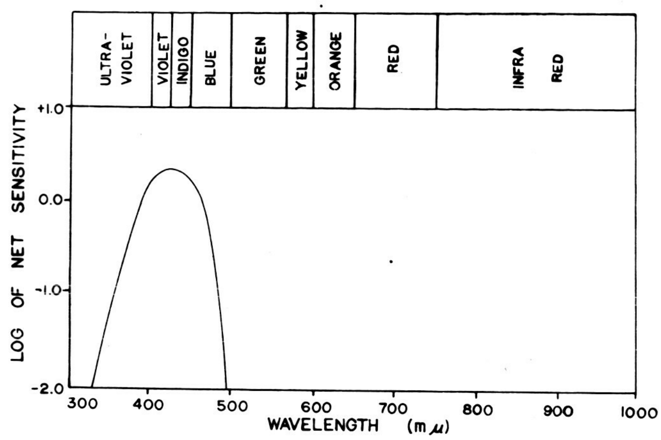
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Catwalk of Water Tower, Davis, California

Distance from Target Array: 150 feet

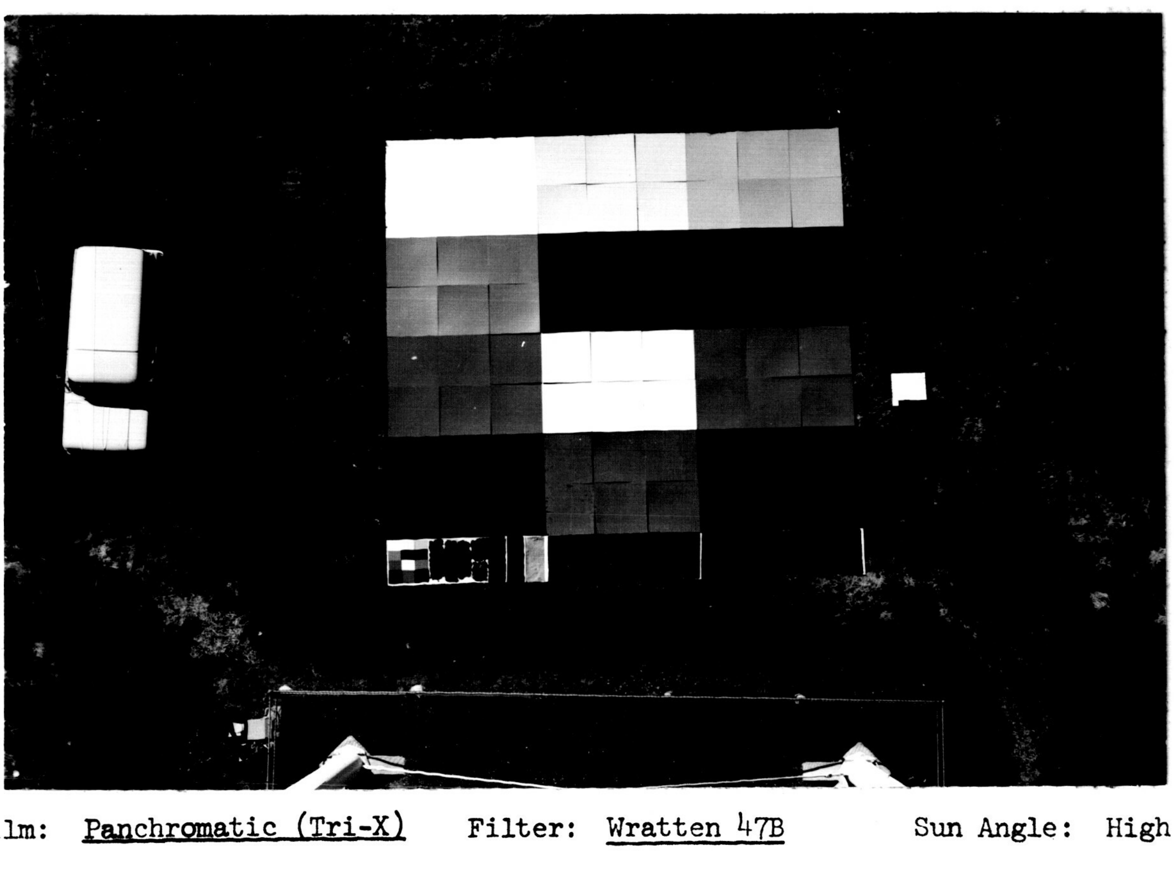
Camera Used: Speed Graphic with focal length of 127 mm.

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY



Film: Panchromatic (Tri-X) Filter: Wratten 47B Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 47B

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 104 | 100 | 100 | 89 |
| Black Fine Cinders | 5 | 20 | 24 | 35 | 20 | 37 |
| Red Fine Cinders | 22 | 56 | 39 | 67 | 56 | 63 |
| Red Coarse Cinders | 0 | 31 | 20 | 0 | 31 | 9 |
| Rough Lava | 0 | 0 | 20 | 0 | 0 | 9 |
| Computed K-S Maximum | 0.630* | | 0.098* | 0.153* | | 0.064 |
| K-S Statistic | 0.121 | | 0.094 | 0.096 | | 0.094 |
| Coefficient of Correlation | | 0.92 | | | 0.91 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

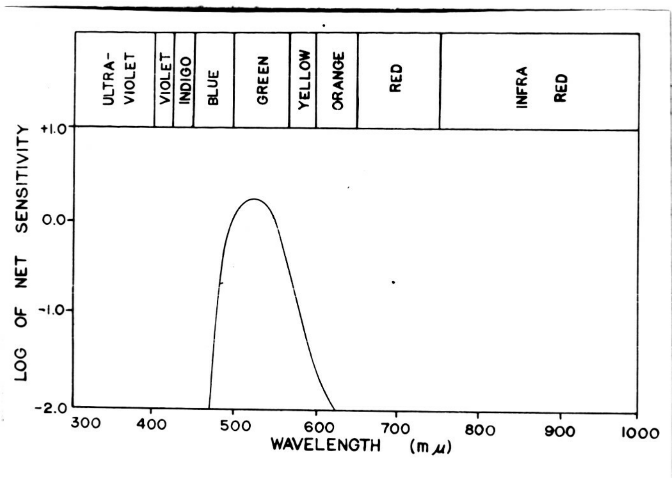
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

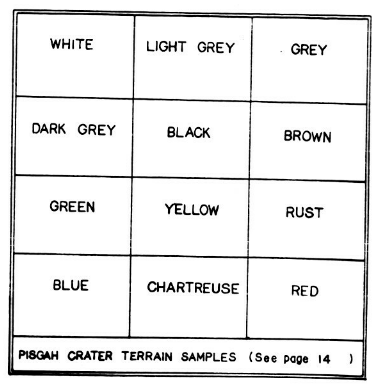
Camera Station: Catwalk of Water Tower, Davis, California

Distance from Target Array: 150 feet

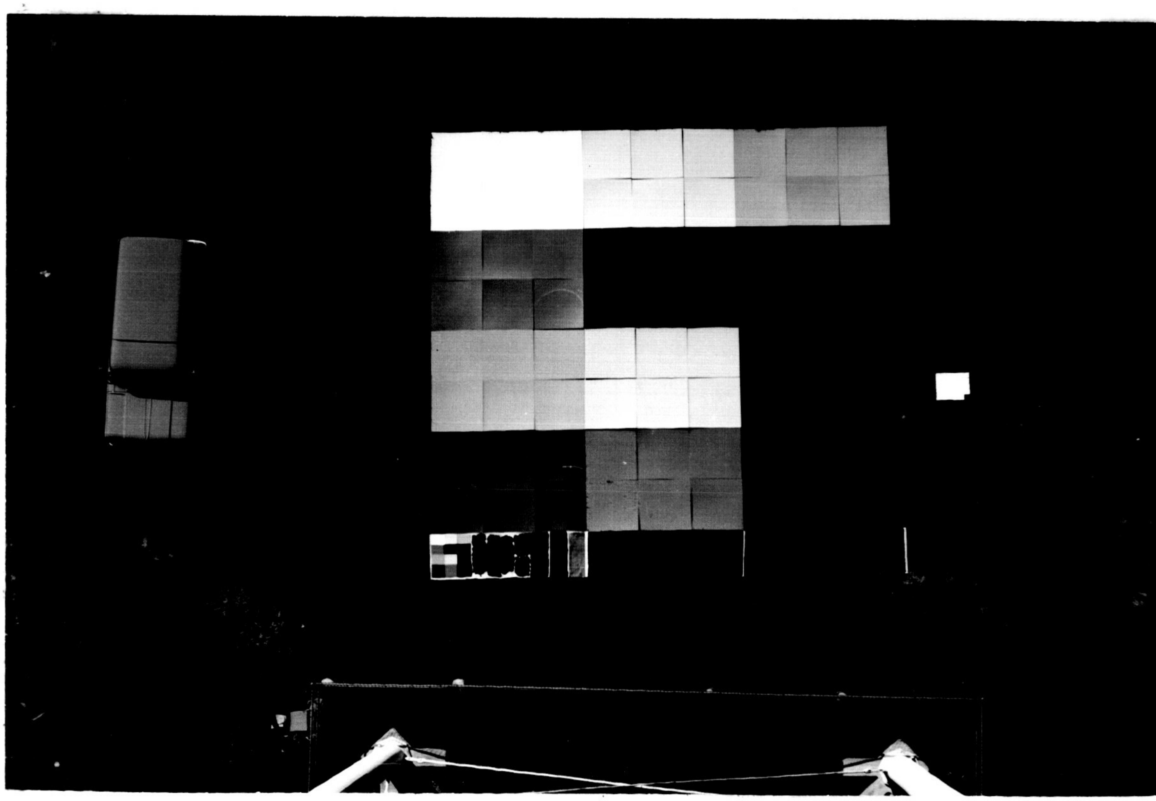
Camera Used: Speed Graphic with focal length of 127 mm.

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




TARGET ARRAY



Film: Panchromatic (Tri-X) Filter: Wratten 61 Sun Angle: High

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 135 | 100 | 100 | 117 |
| Light Grey | 55 | 97 | 91 | 87 | 97 | 102 |
| Medium Grey | 36 | 92 | 73 | 78 | 92 | 91 |
| Dark Grey | 21 | 85 | 59 | 66 | 85 | 77 |
| Brown | 3 | 51 | 42 | 24 | 51 | 28 |
| Green | 32 | 92 | 69 | 75 | 92 | 88 |
| Yellow | 52 | 97 | 89 | 86 | 97 | 101 |
| Rust | 3 | 44 | 42 | 24 | 44 | 28 |
| Blue | 12 | 77 | 50 | 54 | 77 | 63 |
| Chartreuse | 20 | 86 | 58 | 65 | 86 | 76 |
| Red | 2 | -34 | 41 | 15 | -34 | 17 |
| Black | 0 | 0 | 39 | 0 | 0 | -1 |
| Computed K-S Maximum | 1.342* | 0.144* | | 0.168* | 0.064 | |
| K-S Statistic | 0.074 | 0.048 | | 0.052 | 0.048 | |
| Coefficient of Correlation | 0.66 | | | 0.89 | | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: Pritchard (Portable)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Light Grey | 100 | 100 | 129 | 100 | 100 | 112 |
| Medium Grey | 68 | 93 | 80 | 92 | 93 | 98 |
| Dark Grey | 38 | 73 | 35 | 79 | 73 | 77 |
| Yellow | 108 | 100 | 141 | 102 | 100 | 115 |
| Rust | -1 | -13 | -25 | 0 | -13 | -54 |
| Chartreuse | 35 | 80 | 30 | 77 | 80 | 74 |
| Red | -4 | -180 | -29 | -30 | -180 | -104 |
| Green | 57 | 93 | 64 | 88 | 93 | 92 |
| Blue | 18 | 60 | 4 | 63 | 60 | 50 |
| Brown | 0 | 0 | -23 | 0 | 0 | -54 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.438* | 0.269* | 0.268* | 0.092* |
| K-S Statistic | 0.066 | 0.058 | 0.054 | 0.047 |
| Coefficient of Correlation | 0.71 | | 0.92 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 103 | 100 | 100 | 82 |
| Black Fine Cinders | 3 | -16 | 1 | 24 | -16 | 1 |
| Red Coarse Cinders | 8 | 9 | 6 | 45 | 9 | 23 |
| Red Fine Cinders | 21 | 34 | 20 | 66 | 34 | 46 |
| Rough Lava | 0 | 0 | -2 | 0 | 0 | -25 |
| Computed K-S Maximum | 0.144* | | 0.110 | 0.460* | | 0.140* |
| K-S Statistic | 0.118 | | 0.118 | 0.089 | | 0.102 |
| Coefficient of Correlation | | 0.97 | | | 0.90 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 103 | 100 | 100 | 85 |
| Black Fine Cinders | 3 | -16 | 2 | 24 | -16 | 4 |
| Red Fine Cinders | 21 | 34 | 21 | 66 | 34 | 49 |
| Red Coarse Cinders | 4 | 9 | 3 | 30 | 9 | 11 |
| Rough Lava | 0 | 0 | -1 | 0 | 0 | -21 |
| Computed K-S Maximum | | 0.148* | 0.130* | | 0.423* | 0.126* |
| K-S Statistic | | 0.120 | 0.120 | | 0.092 | 0.104 |
| Coefficient of Correlation | | 0.97 | | | 0.92 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

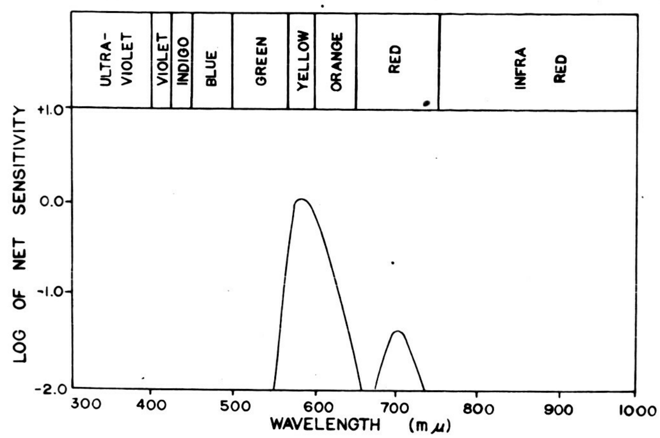
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

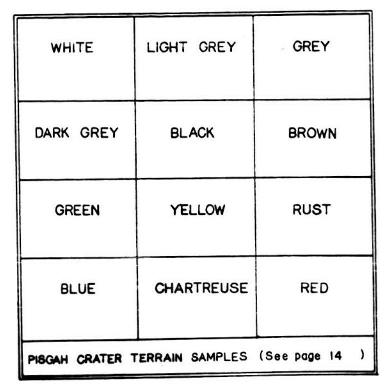
Camera Station: Catwalk of Water Tower, Davis, California

Distance from Target Array: 150 feet

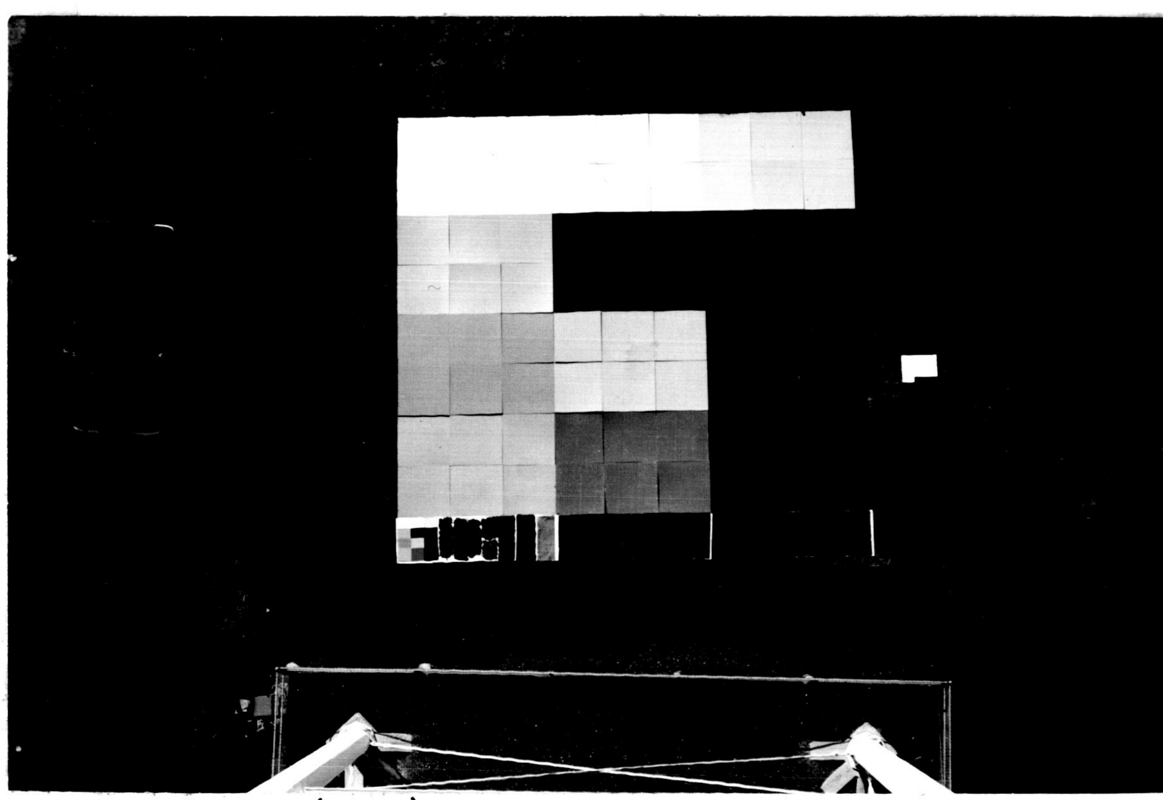
Camera Used: Speed Graphic with focal length of 127 mm.

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




TARGET ARRAY



Film: Panchromatic (Tri-X) Filter: Wratten 90 Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 90

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 119 | 100 | 100 | 109 |
| Light Grey | 54 | 97 | 89 | 87 | 97 | 97 |
| Medium Grey | 36 | 91 | 77 | 78 | 91 | 89 |
| Dark Grey | 21 | 86 | 67 | 66 | 86 | 78 |
| Brown | 7 | 57 | 58 | 42 | 57 | 56 |
| Green | 12 | 82 | 61 | 54 | 82 | 66 |
| Yellow | 69 | 99 | 99 | 92 | 99 | 102 |
| Rust | 25 | 80 | 69 | 70 | 80 | 81 |
| Blue | 3 | 53 | 55 | 24 | 53 | 38 |
| Chartreuse | 13 | 81 | 62 | 56 | 81 | 68 |
| Red | 13 | 43 | 62 | 56 | 43 | 68 |
| Black | 0 | 0 | 53 | 0 | 0 | 16 |
| Computed K-S Maximum | 1.462* | 0.064* | | 0.200* | 0.032 | |
| K-S Statistic | 0.072 | 0.046 | | 0.050 | 0.046 | |
| Coefficient of Correlation | | 0.68 | | | 0.91 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 90

Sun Angle: High

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 107 | 100 | 100 | 85 |
| Red | 11 | -29 | 26 | 52 | -29 | 37 |
| Rust | 31 | 57 | 44 | 75 | 57 | 60 |
| Chartreuse | 14 | 57 | 29 | 57 | 57 | 42 |
| Green | 13 | 64 | 28 | 56 | 64 | 41 |
| Blue | 0 | 0 | 16 | 0 | 0 | -16 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.473* | 0.285* | 0.267* | 0.180* |
| K-S Statistic | 0.105 | 0.086 | 0.074 | 0.081 |
| Coefficient of Correlation | 0.70 | | 0.71 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 90

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 104 | 100 | 100 | 88 |
| Black Fine Cinders | -1 | 8 | 13 | 0 | 8 | -1 |
| Red Coarse Cinders | 9 | 25 | 22 | 48 | 25 | 41 |
| Red Fine Cinders | 20 | 51 | 32 | 65 | 51 | 57 |
| Rough Lava | 0 | 0 | 14 | 0 | 0 | -1 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.431* | 0.100* | 0.135* | 0.062 |
| K-S Statistic | 0.119 | 0.099 | 0.093 | 0.099 |
| Coefficient of Correlation | 0.95 | | 0.95 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 90

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 104 | 100 | 100 | 88 |
| Black Fine Cinders | 2 | 8 | 13 | 15 | 8 | 7 |
| Red Fine Cinders | 25 | 51 | 35 | 70 | 51 | 59 |
| Red Coarse Cinders | 9 | 25 | 20 | 48 | 25 | 38 |
| Rough Lava | 0 | 0 | 12 | 0 | 0 | -8 |
| Computed K-S Maximum | 0.353* | 0.092 | | 0.209* | 0.059 | |
| K-S Statistic | 0.117 | 0.100 | | 0.089 | 0.096 | |
| Coefficient of Correlation | | 0.96 | | | 0.96 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

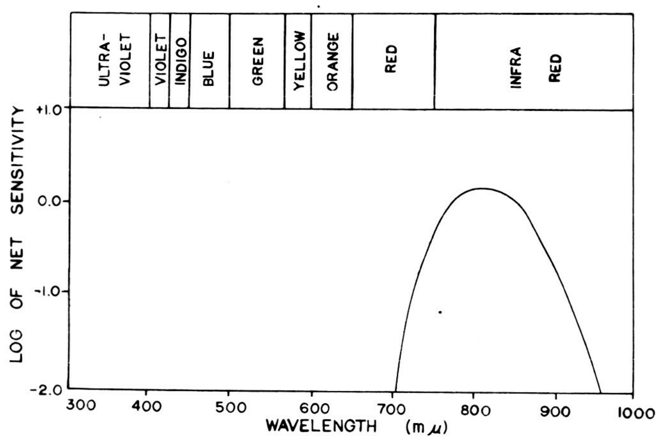
**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples

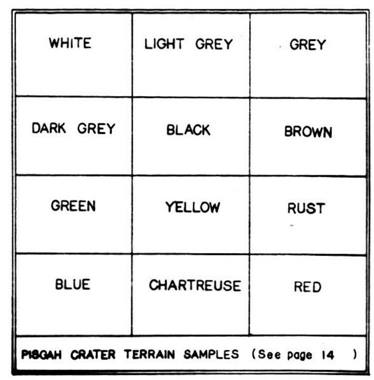
**Camera Station:** Catwalk of Water Tower, Davis, California

**Distance from Target Array:** 150 feet

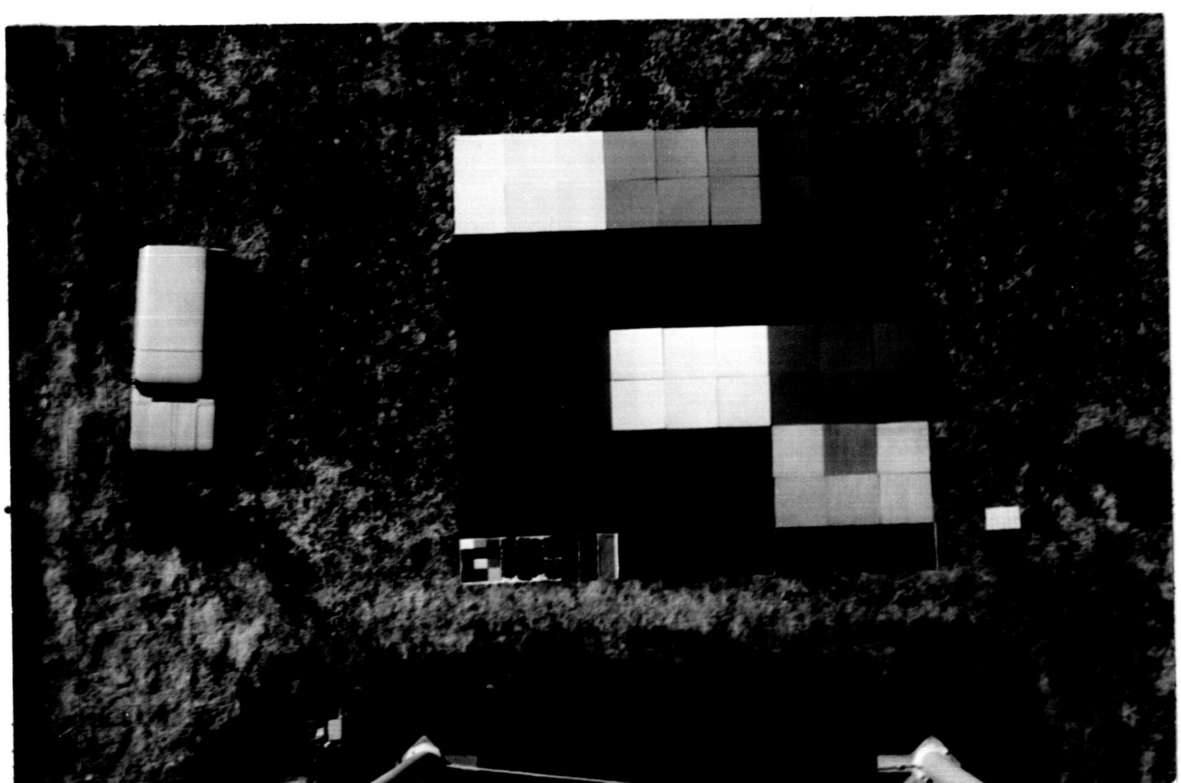
**Camera Used:** Speed Graphic with focal length of 127 mm.

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175 °K




TARGET ARRAY



Film: Infrared          Filter: Wratten 89B          Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Infrared, Wratten 89B

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 119 | 100 | 100 | 114 |
| Light Grey | 49 | 98 | 90 | 85 | 98 | 99 |
| Medium Grey | 31 | 93 | 80 | 75 | 93 | 89 |
| Dark Grey | 17 | 87 | 72 | 62 | 87 | 76 |
| Brown | 7 | 65 | 66 | 42 | 65 | 57 |
| Green | 28 | 93 | 78 | 72 | 93 | 87 |
| Yellow | 77 | 100 | 106 | 94 | 100 | 109 |
| Rust | 33 | 93 | 81 | 76 | 93 | 91 |
| Blue | 17 | 86 | 72 | 62 | 86 | 76 |
| Chartreuse | 28 | 93 | 78 | 72 | 93 | 87 |
| Red | 67 | 99 | 100 | 91 | 99 | 106 |
| Black | 0 | 0 | 63 | 0 | 0 | 16 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.121* | 0.064* | 0.212* | 0.030 |
| K-S Statistic | 0.064 | 0.043 | 0.047 | 0.043 |
| Coefficient of Correlation | 0.60 | | 0.95 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Infrared, Wratten 89B

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 106 | 100 | 100 | 84 |
| Black Fine Cinders | -3 | -3 | 8 | -3 | -24 | -14 |
| Red Coarse Cinders | 14 | 30 | 24 | 30 | 57 | 50 |
| Red Fine Cinders | 22 | 55 | 32 | 55 | 67 | 58 |
| Rough Lava | 0 | 0 | 11 | 0 | 0 | 5 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.352* | 0.123* | 0.084 | 0.076 |
| K-S Statistic | 0.115 | 0.101 | 0.086 | 0.094 |
| Coefficient of Correlation | 0.94 | | 0.94 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Infrared, Wratten 89B

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

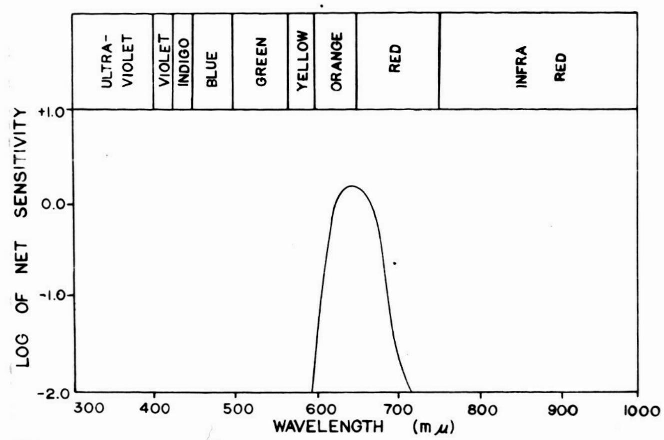
| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 106 | 100 | 100 | 83 |
| Black Fine Cinders | -1 | -3 | 5 | 0 | -3 | -6 |
| Red Fine Cinders | 38 | 55 | 44 | 79 | 55 | 64 |
| Red Coarse Cinders | 15 | 30 | 21 | 59 | 30 | 46 |
| Rough Lava | 0 | 0 | 6 | 0 | 0 | -6 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.195* | 0.079 | 0.235* | 0.083 |
| K-S Statistic | 0.110 | 0.101 | 0.088 | 0.095 |
| Coefficient of Correlation | 0.98 | | 0.95 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

**Type of Target:** Masonite Color Panels and Pisgah Crater Terrain Samples
**Camera Station:** Catwalk of Water Tower, Davis, California
**Distance from Target Array:** 150 feet
**Camera Used:** Speed Graphic with focal length of 127 mm.
**Color Temperature Reading of Daylight Sky:** 10 units, or 5175°K
**Film-Filter Combination:** Panchromatic (Tri-X); Wratten 25A

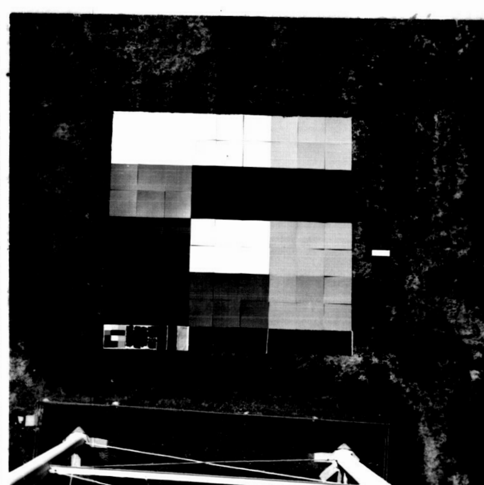


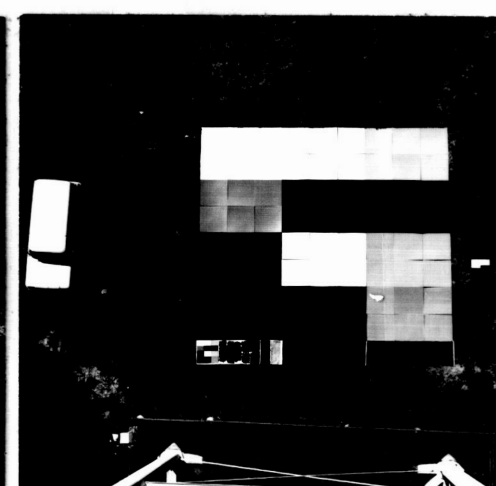

| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY

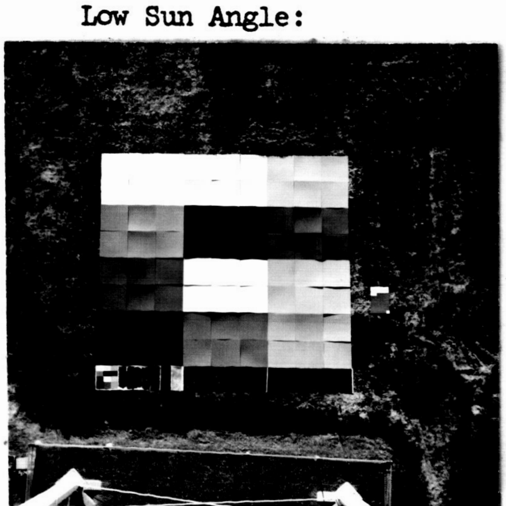
**High Sun Angle:**

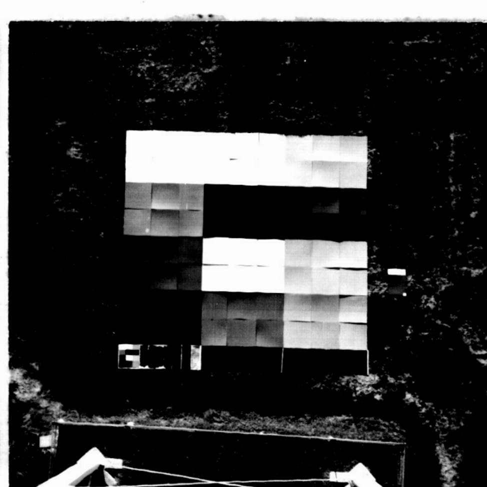

1/250 second at f 4.7


1/250 second at f 8


1/250 second at f 16

**Low Sun Angle:**

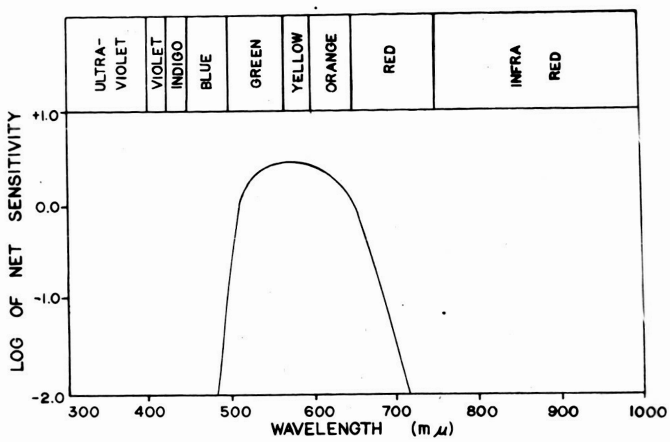

1/250 second at f 4.7


1/250 second at f 8


1/250 second at f 16

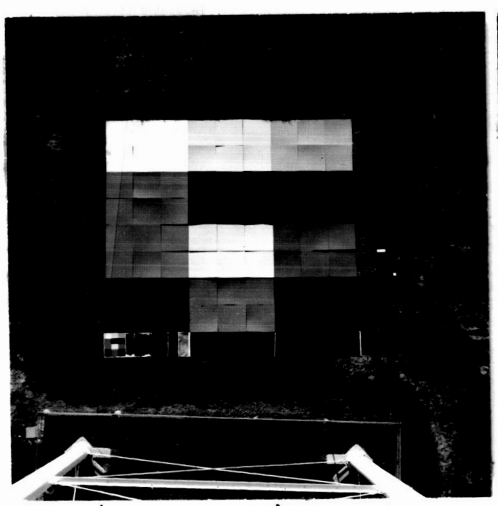
MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples
Camera Station: Catwalk of Water Tower, Davis, California
Distance from Target Array: 150 feet
Camera Used: Speed Graphic with focal length of 127 mm.
Color Temperature Reading of Daylight Sky: 11 units, or 5200 °K
Film-Filter Combination: Panchromatic (Tri-X); Wratten 12
Sun Angle: Low

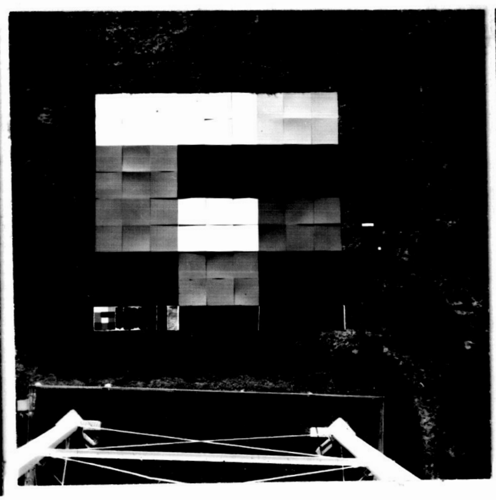



| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14) | | |

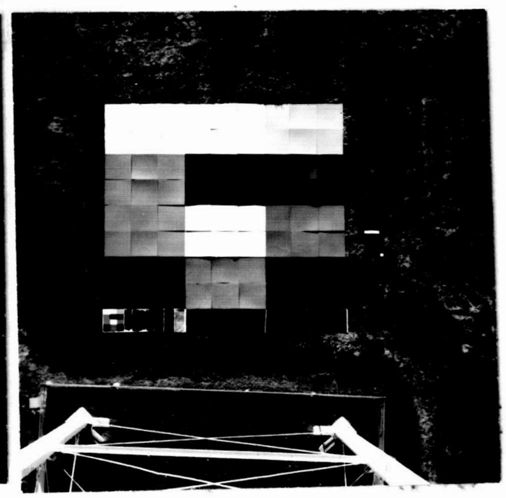
TARGET ARRAY



1/250 second at f 16
Camera 1



1/250 second at f 16
Camera 1



1/250 second at f 16
Camera 2

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (TR1-X), Wratten 12

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 121 | 100 | 100 | 104 |
| Light Grey | 54 | 94 | 84 | 87 | 94 | 90 |
| Medium Grey | 36 | 79 | 69 | 78 | 79 | 81 |
| Dark Grey | 21 | 71 | 57 | 66 | 71 | 69 |
| Brown | 6 | 35 | 45 | 39 | 35 | 40 |
| Green | 17 | 72 | 54 | 62 | 72 | 64 |
| Yellow | 65 | 98 | 93 | 91 | 98 | 94 |
| Rust | 20 | 65 | 56 | 65 | 65 | 68 |
| Blue | 5 | 42 | 44 | 35 | 42 | 36 |
| Chartreuse | 15 | 71 | 52 | 59 | 71 | 61 |
| Red | 15 | 40 | 52 | 59 | 40 | 61 |
| Black | 0 | 0 | 40 | 0 | 0 | 0 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.167* | 0.084* | 0.038 | 0.026 |
| K-S Statistic | 0.072 | 0.049 | 0.050 | 0.049 |
| Coefficient of Correlation | 0.80 | | 0.96 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (TR1-X), Wratten 12

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 120 | 100 | 100 | 104 |
| Light Grey | 54 | 94 | 83 | 87 | 94 | 90 |
| Medium Grey | 36 | 77 | 69 | 78 | 77 | 81 |
| Dark Grey | 21 | 72 | 57 | 66 | 72 | 69 |
| Brown | 6 | 36 | 45 | 39 | 36 | 41 |
| Green | 17 | 72 | 54 | 62 | 72 | 64 |
| Yellow | 65 | 96 | 92 | 91 | 96 | 94 |
| Rust | 20 | 65 | 57 | 65 | 65 | 68 |
| Blue | 5 | 42 | 45 | 35 | 42 | 37 |
| Chartreuse | 15 | 75 | 53 | 59 | 75 | 61 |
| Red | 15 | 39 | 53 | 59 | 39 | 61 |
| Black | 0 | 0 | 41 | 0 | 0 | 1 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.170* | 0.069* | 0.039* | 0.018 |
| K-S Statistic | 0.072 | 0.049 | 0.050 | 0.049 |
| Coefficient of Correlation | 0.79 | | 0.95 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Davis

Film-Filter: Panchromatic (Tri-X), Wratten 12 (Camera #2)

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 122 | 100 | 100 | 105 |
| Light Grey | 54 | 94 | 84 | 87 | 94 | 91 |
| Medium Grey | 36 | 86 | 69 | 78 | 86 | 81 |
| Dark Grey | 21 | 70 | 57 | 66 | 70 | 69 |
| Brown | 6 | 23 | 45 | 39 | 23 | 40 |
| Green | 17 | 70 | 54 | 62 | 70 | 64 |
| Yellow | 65 | 96 | 93 | 91 | 96 | 95 |
| Rust | 20 | 67 | 56 | 65 | 67 | 68 |
| Blue | 5 | 43 | 44 | 35 | 43 | 35 |
| Chartreuse | 15 | 71 | 52 | 59 | 71 | 61 |
| Red | 15 | 48 | 52 | 59 | 48 | 61 |
| Black | 0 | 0 | 40 | 0 | 0 | -2 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.170* | 0.081* | 0.039 | 0.013 |
| K-S Statistic | 0.072 | 0.049 | 0.050 | 0.049 |
| Coefficient of Correlation | 0.79 | | 0.97 | |

*Significant at a 95% Confidence Level

MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

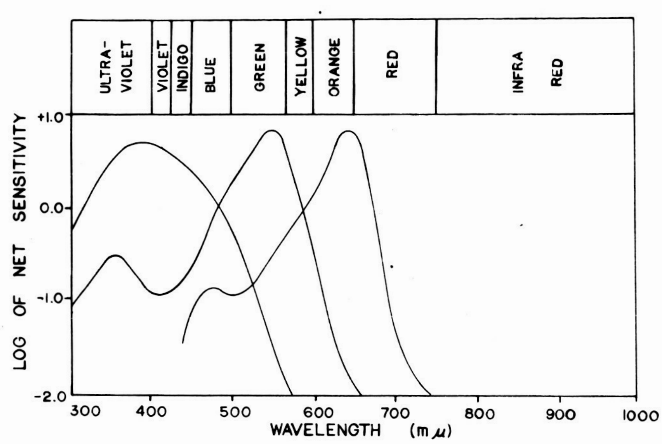
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5280 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY

Film: Ektachrome    Filter: None    Sun Angle: High

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

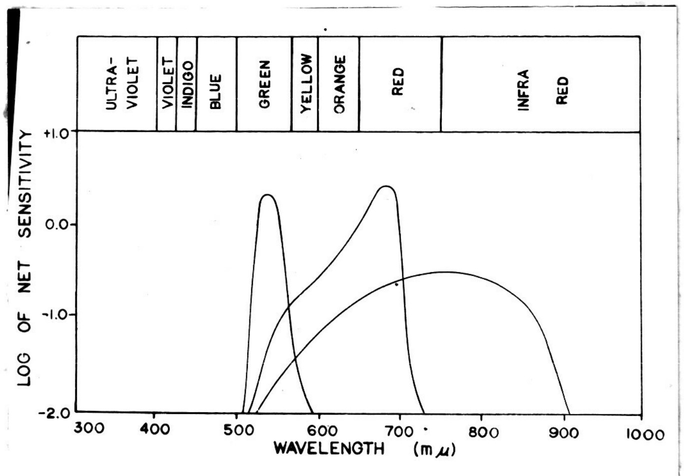
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

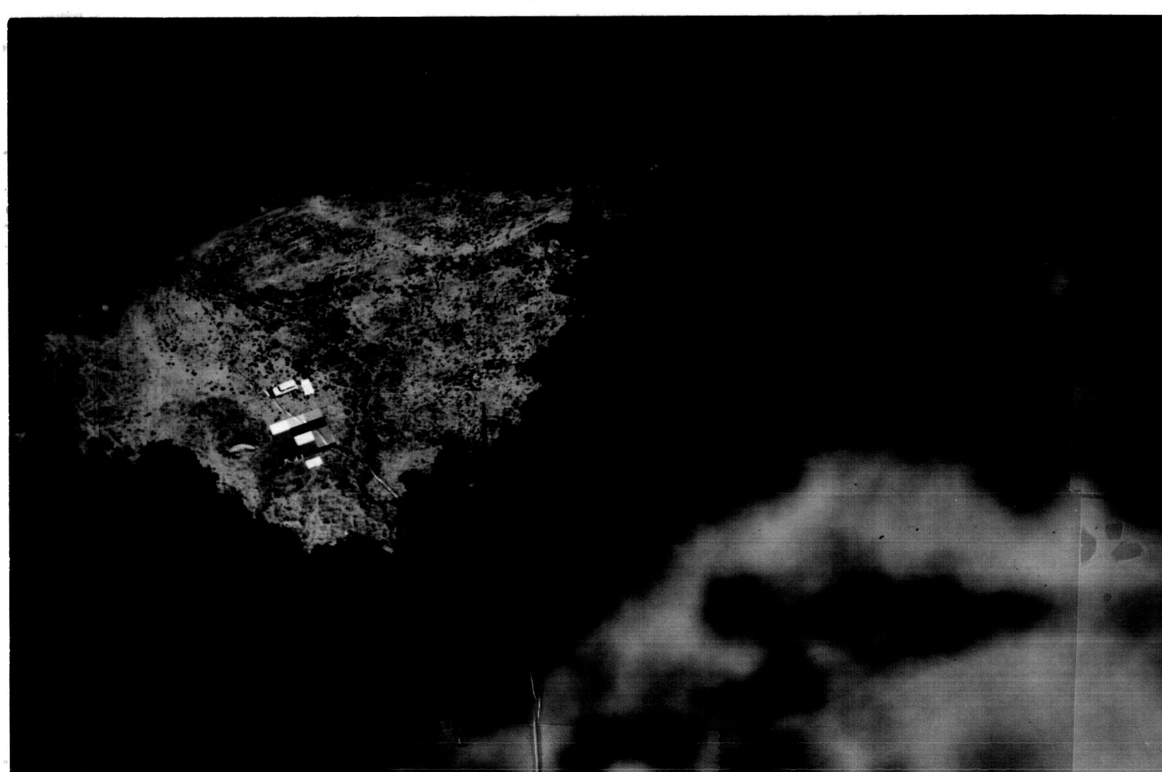
Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5280 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14) | | |

TARGET ARRAY



Film: Camouflage Detection Filter: Wratten 15+EF-2200 Sun Angle: High

MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

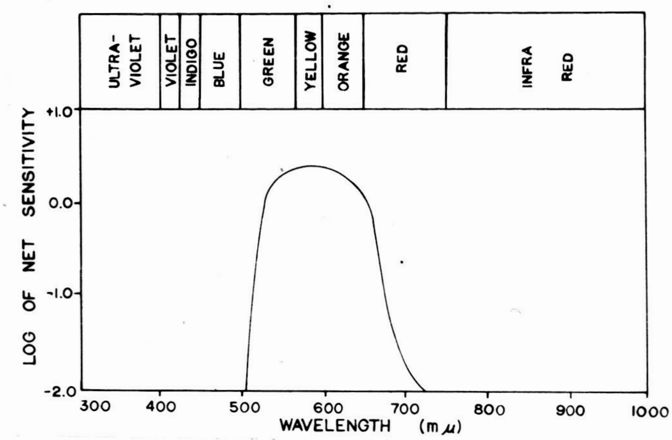
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

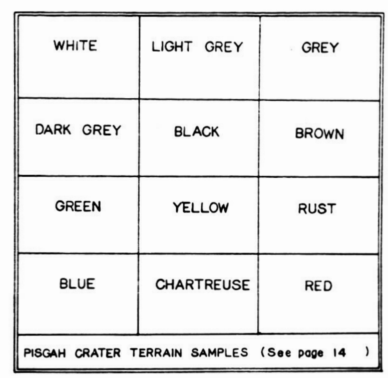
Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5280 °K



TARGET ARRAY

Film: Panchromatic (Tri-X) Filter: Wratten 15 Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (TRl-X), Wratten 15

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 120 | 100 | 100 | 108 |
| Light Grey | 54 | 95 | 87 | 87 | 95 | 95 |
| Medium Grey | 36 | 89 | 74 | 78 | 89 | 86 |
| Dark Grey | 21 | 78 | 63 | 66 | 78 | 74 |
| Brown | 6 | 49 | 52 | 39 | 49 | 47 |
| Green | 15 | 76 | 59 | 59 | 76 | 67 |
| Yellow | 66 | 97 | 96 | 91 | 97 | 99 |
| Rust | 22 | 73 | 64 | 67 | 73 | 75 |
| Blue | 4 | 43 | 51 | 30 | 43 | 38 |
| Chartreuse | 15 | 75 | 59 | 59 | 75 | 67 |
| Red | 16 | 58 | 60 | 60 | 58 | 68 |
| Black | 0 | 0 | 48 | 0 | 0 | 8 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.346* | 0.072* | 0.133* | 0.018 |
| K-S Statistic | 0.072 | 0.047 | 0.050 | 0.047 |
| Coefficient of Correlation | 0.75 | | 0.97 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 15

Sun Angle: High

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 107 | 100 | 100 | 92 |
| Red | 16 | 30 | 42 | 60 | 30 | 53 |
| Rust | 26 | 60 | 49 | 71 | 60 | 63 |
| Chartreuse | 16 | 60 | 42 | 60 | 60 | 53 |
| Green | 16 | 60 | 42 | 60 | 60 | 53 |
| Blue | 0 | 0 | 29 | 0 | 0 | -5 |
| Computed K-S Maximum | | 0.782* | 0.131* | | 0.118* | 0.057 |
| K-S Statistic | | 0.103 | 0.077 | | 0.073 | 0.076 |
| Coefficient of Correlation | | 0.82 | | | 0.93 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 15

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 100 | 100 | 100 | 74 |
| Black Fine Cinders | -1 | -18 | -7 | 0 | -18 | -17 |
| Red Coarse Cinders | 9 | 16 | 4 | 48 | 16 | 26 |
| Red Fine Cinders | 20 | 9 | 15 | 65 | 9 | 42 |
| Rough Lava | 0 | 0 | -6 | 0 | 0 | -17 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.162* | 0.049 | 0.497* | 0.149* |
| K-S Statistic | 0.119 | 0.119 | 0.093 | 0.102 |
| Coefficient of Correlation | 0.98 | | 0.86 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 15

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 98 | 100 | 100 | 71 |
| Black Fine Cinders | 2 | -18 | -5 | 15 | -18 | -8 |
| Red Fine Cinders | 25 | 9 | 19 | 70 | 9 | 43 |
| Red Coarse Cinders | 9 | 16 | 2 | 48 | 16 | 23 |
| Rough Lava | 0 | 0 | -7 | 0 | 0 | -22 |
| Computed K-S Maximum | | 0.213* | 0.065 | | 0.540* | 0.170* |
| K-S Statistic | | 0.117 | 0.118 | | 0.089 | 0.105 |
| Coefficient of Correlation | | 0.97 | | | 0.83 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

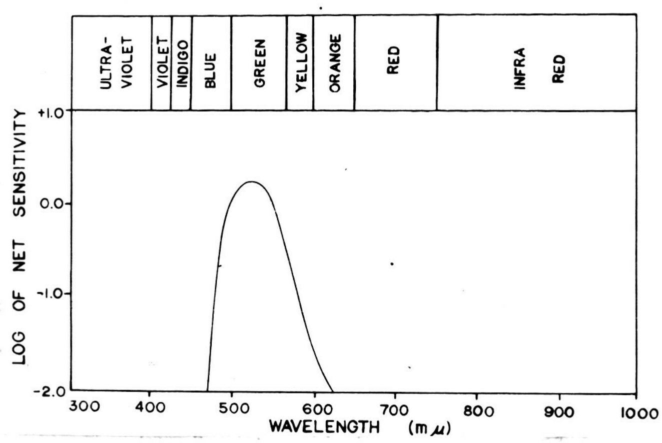
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5280 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY

Film: Panchromatic (Tri-X) Filter: Wratten 61 Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Trl-X), Wratten 61

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 137 | 100 | 100 | 116 |
| Light Grey | 55 | 95 | 89 | 87 | 95 | 100 |
| Medium Grey | 36 | 91 | 69 | 78 | 91 | 88 |
| Dark Grey | 21 | 82 | 53 | 66 | 82 | 73 |
| Brown | 3 | 32 | 34 | 24 | 32 | 20 |
| Green | 32 | 88 | 65 | 75 | 88 | 85 |
| Yellow | 52 | 95 | 86 | 86 | 95 | 98 |
| Rust | 3 | 27 | 34 | 24 | 27 | 20 |
| Blue | 12 | 70 | 44 | 54 | 70 | 58 |
| Chartreuse | 20 | 83 | 52 | 65 | 83 | 72 |
| Red | 2 | -35 | 33 | 15 | -35 | 9 |
| Black | 0 | 0 | 31 | 0 | 0 | -10 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.167* | 0.149* | 0.080* | 0.045 |
| K-S Statistic | 0.074 | 0.050 | 0.052 | 0.050 |
| Coefficient of Correlation | 0.71 | | 0.93 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: Pritchard (Portable)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Light Grey | 100 | 100 | 110 | 100 | 100 | 92 |
| Medium Grey | 68 | 83 | 72 | 92 | 83 | 83 |
| Dark Grey | 38 | 67 | 37 | 79 | 67 | 68 |
| Yellow | 108 | 100 | 119 | 102 | 100 | 94 |
| Rust | -1 | 0 | -9 | 0 | 0 | -26 |
| Chartreuse | 35 | 83 | 33 | 77 | 83 | 65 |
| Red | -4 | -100 | -12 | -30 | -100 | -61 |
| Green | 57 | 33 | 59 | 88 | 33 | 78 |
| Blue | 18 | 50 | 13 | 63 | 50 | 48 |
| Brown | 0 | 0 | -8 | 0 | 0 | -26 |
| Computed K-S Maximum | | 0.224* | 0.185* | | 0.244* | 0.060* |
| K-S Statistic | | 0.066 | 0.062 | | 0.054 | 0.054 |
| Coefficient of Correlation | | 0.78 | | | 0.92 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 100 | 100 | 100 | 74 |
| Black Fine Cinders | 3 | -33 | -8 | 24 | -33 | -6 |
| Red Coarse Cinders | 8 | 13 | -2 | 45 | 13 | 16 |
| Red Fine Cinders | 21 | 11 | 12 | 66 | 11 | 38 |
| Rough Lava | 0 | 0 | -11 | 0 | 0 | -31 |
| Computed K-S Maximum | 0.311* | 0.104 | | 0.613* | 0.189* | |
| K-S Statistic | 0.118 | 0.118 | | 0.089 | 0.106 | |
| Coefficient of Correlation | 0.95 | | | 0.82 | | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 61

Sun Angle: High

Spetrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 99 | 100 | 100 | 76 |
| Black Fine Cinders | 3 | -33 | -6 | 24 | -33 | -3 |
| Red Fine Cinders | 21 | 11 | 13 | 66 | 11 | 41 |
| Red Coarse Cinders | 4 | 13 | -5 | 30 | 13 | 4 |
| Rough Lava | 0 | 0 | -10 | 0 | 0 | -27 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.289* | 0.125* | 0.586* | 0.180* |
| K-S Statistic | 0.120 | 0.117 | 0.092 | 0.111 |
| Coefficient of Correlation | 0.94 | | 0.82 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

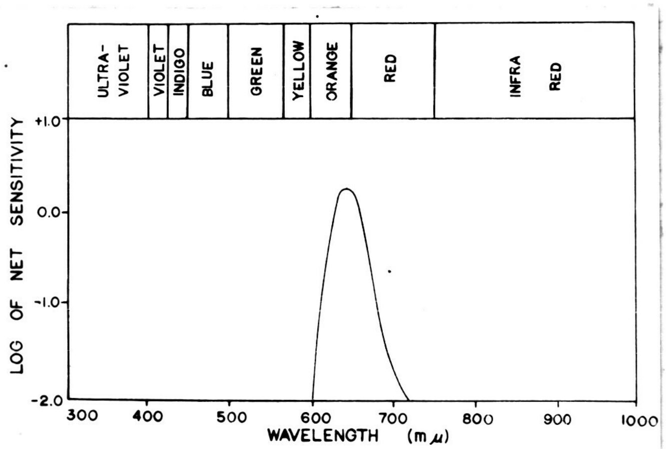
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

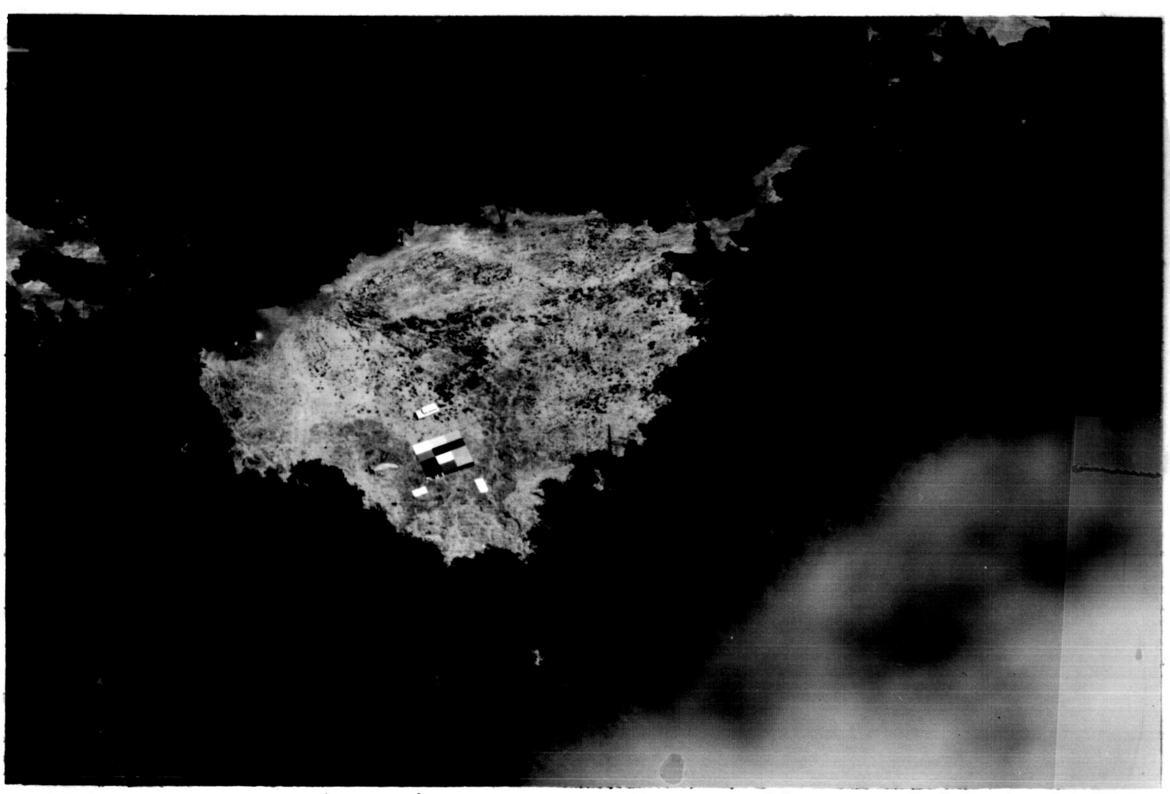
Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5280 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14) | | |

TARGET ARRAY



Film: Panchromatic (Tri-X) Filter: Wratten 29 Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Trl-X), Wratten 29

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 123 | 100 | 100 | 108 |
| Light Grey | 52 | 94 | 84 | 86 | 94 | 93 |
| Medium Grey | 35 | 88 | 70 | 77 | 88 | 84 |
| Dark Grey | 20 | 75 | 58 | 65 | 75 | 71 |
| Brown | 8 | 55 | 48 | 45 | 55 | 50 |
| Green | 8 | 57 | 48 | 45 | 57 | 50 |
| Yellow | 73 | 98 | 101 | 93 | 98 | 101 |
| Rust | 36 | 86 | 71 | 78 | 86 | 85 |
| Blue | 3 | 18 | 44 | 24 | 18 | 28 |
| Chartreuse | 13 | 66 | 53 | 56 | 66 | 61 |
| Red | 48 | 88 | 81 | 84 | 88 | 91 |
| Black | 0 | 0 | 42 | 0 | 0 | 3 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.083* | 0.083* | 0.096* | 0.016 |
| K-S Statistic | 0.068 | 0.047 | 0.050 | 0.047 |
| Coefficient of Correlation | 0.79 | | 0.99 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 29

Sun Angle: High

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 110 | 100 | 100 | 99 |
| Red | 62 | 83 | 82 | 90 | 83 | 90 |
| Rust | 45 | 83 | 69 | 83 | 83 | 84 |
| Chartreuse | 13 | 61 | 46 | 56 | 61 | 59 |
| Green | 6 | 56 | 40 | 39 | 56 | 43 |
| Blue | 0 | 0 | 36 | 0 | 0 | 8 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.695* | 0.094* | 0.062 | 0.020 |
| K-S Statistic | 0.090 | 0.070 | 0.071 | 0.070 |
| Coefficient of Correlation | 0.82 | | 0.98 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 29

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 100 | 100 | 100 | 72 |
| Black Fine Cinders | -2 | -21 | -7 | -15 | -21 | -24 |
| Red Coarse Cinders | 10 | 25 | 5 | 50 | 25 | 30 |
| Red Fine Cinders | 21 | 6 | 17 | 66 | 6 | 44 |
| Rough Lava | 0 | 0 | -5 | 0 | 0 | -12 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.143* | 0.102 | 0.394* | 0.154* |
| K-S Statistic | 0.118 | 0.117 | 0.089 | 0.101 |
| Coefficient of Correlation | 0.96 | | 0.85 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Panchromatic (Tri-X), Wratten 29

Sun Angle: High

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 96 | 100 | 100 | 67 |
| Black Fine Cinders | 2 | -21 | -7 | 15 | -21 | -8 |
| Red Fine Cinders | 33 | 6 | 26 | 76 | 6 | 46 |
| Red Coarse Cinders | 17 | 25 | 4 | 54 | 25 | 26 |
| Rough Lava | 0 | 0 | -9 | 0 | 0 | -21 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.252* | 0.110 | 0.551* | 0.195* |
| K-S Statistic | 0.112 | 0.115 | 0.087 | 0.105 |
| Coefficient of Correlation | 0.93 | | 0.79 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

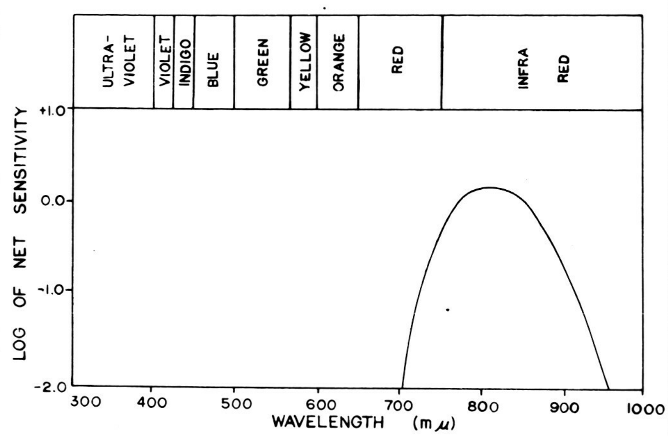
Type of Target: Masonite Color Panels and Pisgah Crater Terrain Samples

Camera Station: Glacier Point, Yosemite National Park, California

Distance from Target Array: 4,200 feet

Camera Used: Graphlex camera with focal length of 20 inches

Color Temperature Reading of Daylight Sky: 14 units, or 5200 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |
| PISGAH CRATER TERRAIN SAMPLES (See page 14 ) | | |

TARGET ARRAY

Film: Infrared  Filter: Wratten 89B  Sun Angle: High

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Yosemite

Film-Filter: Infrared, Wratten 89B

Sun Angle: High

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

Prediction Function

| | Linear | | | Logarithmic | | |
|---|---|---|---|---|---|---|
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 113 | 100 | 100 | 85 |
| Light Grey | 49 | 71 | 64 | 85 | 71 | 69 |
| Medium Grey | 31 | 53 | 47 | 75 | 53 | 59 |
| Dark Grey | 17 | 45 | 34 | 62 | 45 | 46 |
| Brown | 7 | 14 | 24 | 42 | 14 | 26 |
| Green | 28 | 45 | 44 | 72 | 45 | 57 |
| Yellow | 77 | 93 | 91 | 94 | 93 | 79 |
| Rust | 33 | 47 | 49 | 76 | 47 | 61 |
| Blue | 17 | 39 | 34 | 62 | 39 | 46 |
| Chartreuse | 28 | 53 | 44 | 72 | 53 | 57 |
| Red | 67 | 84 | 81 | 91 | 84 | 76 |
| Black | 0 | 0 | 18 | 0 | 0 | -17 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.418* | 0.044 | 0.225* | 0.056* |
| K-S Statistic | 0.064 | 0.054 | 0.047 | 0.052 |
| Coefficient of Correlation | 0.95 | | 0.93 | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

**Test Area:** Pisgah Crater

**Film-Filter:** Panchromatic, Wratten 12

**Sun Angle:** Low

**Spectrophotometer:** General Electric (Laboratory)

**Target:** Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 124 | 100 | 100 | 102 |
| Light Grey | 54 | 91 | 81 | 87 | 91 | 87 |
| Medium Grey | 36 | 85 | 65 | 78 | 85 | 77 |
| Dark Grey | 21 | 64 | 51 | 66 | 64 | 64 |
| Brown | 6 | 38 | 37 | 39 | 38 | 33 |
| Green | 17 | 53 | 47 | 62 | 53 | 59 |
| Yellow | 65 | 100 | 91 | 91 | 100 | 91 |
| Rust | 20 | 59 | 50 | 65 | 59 | 63 |
| Blue | 5 | 18 | 36 | 35 | 18 | 29 |
| Chartreuse | 15 | 57 | 45 | 59 | 57 | 56 |
| Red | 15 | 40 | 45 | 59 | 40 | 56 |
| Black | 0 | 0 | 32 | 0 | 0 | -10 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.992* | 0.077* | 0.075* | 0.027 |
| K-S Statistic | 0.072 | 0.051 | 0.050 | 0.050 |
| Coefficient of Correlation | 0.86 | | 0.97 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 12

Sun Angle: Low

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 105 | 100 | 100 | 84 |
| Red | 13 | 27 | 31 | 56 | 24 | 42 |
| Rust | 23 | 50 | 40 | 68 | 50 | 54 |
| Chartreuse | 17 | 48 | 35 | 62 | 48 | 48 |
| Green | 19 | 42 | 36 | 64 | 42 | 50 |
| Blue | 0 | 0 | 20 | 0 | 0 | -11 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.552* | 0.091* | 0.236* | 0.055 |
| K-S Statistic | 0.104 | 0.083 | 0.073 | 0.080 |
| Coefficient of Correlation | 0.93 | | 0.94 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 12

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 107 | 100 | 100 | 102 |
| Fine Black Cinders | 0 | 52 | 45 | 0 | 52 | 25 |
| Fine Red Cinders | 9 | 42 | 50 | 48 | 42 | 62 |
| Coarse Black Cinders | 6 | 47 | 49 | 39 | 47 | 55 |
| Coarse Red Cinders | 20 | 88 | 57 | 65 | 88 | 75 |
| Smooth Lava | 7 | 73 | 49 | 42 | 73 | 58 |
| Rough Lava | 0 | 0 | 45 | 0 | 0 | 25 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.831* | 0.112* | 0.368* | 0.062 |
| K-S Statistic | 0.114 | 0.068 | 0.079 | 0.068 |
| Coefficient of Correlation | 0.67 | | 0.82 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 12

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 112 | 100 | 100 | 105 |
| Fine Black Cinders | 2 | 52 | 46 | 15 | 52 | 29 |
| Fine Red Cinders | 6 | 47 | 49 | 39 | 47 | 50 |
| Coarse Black Cinders | 25 | 88 | 62 | 70 | 88 | 78 |
| Coarse Red Cinders | 8 | 42 | 50 | 45 | 42 | 56 |
| Desert Pavement | 23 | 76 | 60 | 68 | 76 | 77 |
| Smooth Lava | 15 | 73 | 55 | 59 | 73 | 68 |
| Rough Lava | 0 | 0 | 45 | 0 | 0 | 15 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.670* | 0.101* | 0.207* | 0.032 |
| K-S Statistic | 0.102 | 0.062 | 0.068 | 0.062 |
| Coefficient of Correlation | 0.70 | | 0.92 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

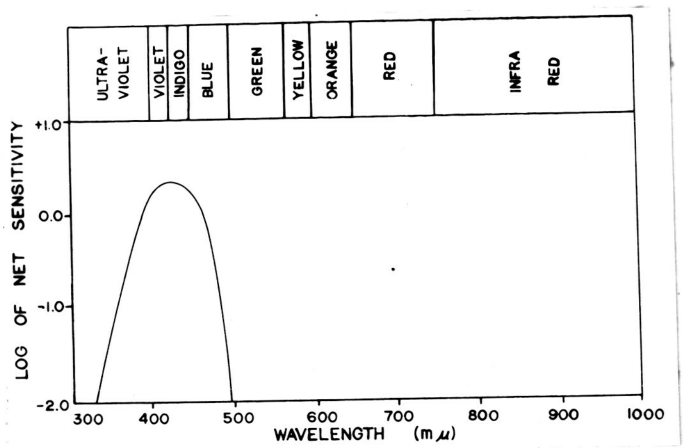
Type of Target: Terrain Types at Pisgah Crater and Masonite Color Panels

Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |

TARGET ARRAY

Film: Panchromatic　　Filter: Wratten 47B　　Sun Angle: Low

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 47B

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 109 | 100 | 100 | 86 |
| Fine Black Cinders | 5 | 16 | 25 | 35 | 16 | 34 |
| Fine Red Cinders | 1 | 16 | 21 | 0 | 16 | 5 |
| Coarse Black Cinders | 22 | 63 | 40 | 67 | 63 | 60 |
| Coarse Red Cinders | 0 | 16 | 20 | 0 | 16 | 5 |
| Desert Pavement | 23 | 52 | 41 | 68 | 52 | 60 |
| Smooth Lava | 16 | 47 | 34 | 60 | 47 | 54 |
| Rough Lava | 0 | 0 | 20 | 0 | 0 | 5 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.856* | 0.122* | 0.097* | 0.051 |
| K-S Statistic | 0.105 | 0.077 | 0.075 | 0.077 |
| Coefficient of Correlation | 0.90 | | 0.94 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 126 | 100 | 100 | 93 |
| Light Grey | 55 | 84 | 76 | 87 | 84 | 79 |
| Medium Grey | 36 | 69 | 55 | 78 | 69 | 69 |
| Dark Grey | 21 | 49 | 38 | 66 | 49 | 57 |
| Brown | 3 | 11 | 18 | 24 | 11 | 11 |
| Green | 32 | 65 | 50 | 75 | 65 | 66 |
| Yellow | 52 | 86 | 72 | 86 | 86 | 78 |
| Rust | 3 | 8 | 18 | 24 | 8 | 11 |
| Blue | 12 | 31 | 28 | 54 | 31 | 43 |
| Chartreuse | 20 | 49 | 37 | 65 | 49 | 55 |
| Red | 2 | -3 | 17 | 15 | -3 | 1 |
| Black | 0 | 0 | 15 | 0 | 0 | -15 |

| | | | | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.634* | 0.094* | 0.185* | 0.035 |
| K-S Statistic | 0.074 | 0.058 | 0.052 | 0.056 |
| Coefficient of Correlation | 0.91 | | 0.98 | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 115 | 100 | 100 | 80 |
| Red | -31 | -61 | -45 | -75 | -61 | -57 |
| Rust | -22 | -41 | -34 | -67 | -41 | -51 |
| Chartreuse | 18 | 33 | 15 | 63 | 33 | 51 |
| Green | 47 | 62 | 50 | 84 | 67 | 68 |
| Blue | 0 | 0 | -7 | 0 | 0 | 2 |
| **Computed K-S Maximum** | 0.225* | | 0.084* | 0.102* | | 0.064 |
| **K-S Statistic** | 0.092 | | 0.083 | 0.069 | | 0.077 |
| **Coefficient of Correlation** | | 0.97 | | | 0.98 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: Pritchard (Portable)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Light Grey | 100 | 100 | 107 | 100 | 100 | 84 |
| Medium Grey | 68 | 79 | 74 | 92 | 79 | 77 |
| Dark Grey | 38 | 52 | 42 | 79 | 52 | 66 |
| Yellow | 108 | 104 | 116 | 102 | 104 | 85 |
| Rust | -1 | -4 | 1 | 0 | -4 | -3 |
| Chartreuse | 35 | 52 | 39 | 77 | 52 | 64 |
| Red | -4 | -20 | -2 | -30 | -20 | -29 |
| Green | 57 | 74 | 62 | 88 | 74 | 73 |
| Blue | 18 | 27 | 21 | 63 | 27 | 51 |
| Brown | 0 | 0 | 2 | 0 | 0 | -3 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.114* | 0.055 | 0.172* | 0.071* |
| K-S Statistic | 0.066 | 0.063 | 0.054 | 0.059 |
| Coefficient of Correlation | 0.97 | | 0.95 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 105 | 100 | 100 | 90 |
| Fine Black Cinders | 3 | 25 | 22 | 24 | 25 | 15 |
| Fine Red Cinders | 8 | 22 | 27 | 45 | 22 | 36 |
| Coarse Black Cinders | 9 | 17 | 28 | 48 | 17 | 38 |
| Coarse Red Cinders | 21 | 61 | 38 | 66 | 61 | 56 |
| Smooth Lava | 11 | 44 | 29 | 52 | 44 | 43 |
| Rough Lava | 0 | 0 | 20 | 0 | 0 | -9 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.770* | 0.121* | 0.197* | 0.066 |
| K-S Statistic | 0.110 | 0.083 | 0.074 | 0.080 |
| Coefficient of Correlation | 0.90 | | 0.93 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 107 | 100 | 100 | 89 |
| Fine Black Cinders | 3 | 25 | 24 | 24 | 25 | 17 |
| Fine Red Cinders | 5 | 17 | 26 | 35 | 17 | 27 |
| Coarse Black Cinders | 21 | 61 | 39 | 66 | 61 | 57 |
| Coarse Red Cinders | 4 | 22 | 25 | 30 | 22 | 23 |
| Desert Pavement | 25 | 50 | 43 | 70 | 50 | 61 |
| Smooth Lava | 15 | 44 | 34 | 59 | 44 | 50 |
| Rough Lava | 0 | 0 | 21 | 0 | 0 | -6 |
| Computed K-S Maximum | 0.844* | 0.098* | | 0.169* | 0.042 | |
| K-S Statistic | 0.103 | 0.076 | | 0.069 | 0.075 | |
| Coefficient of Correlation | | 0.91 | | | 0.96 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

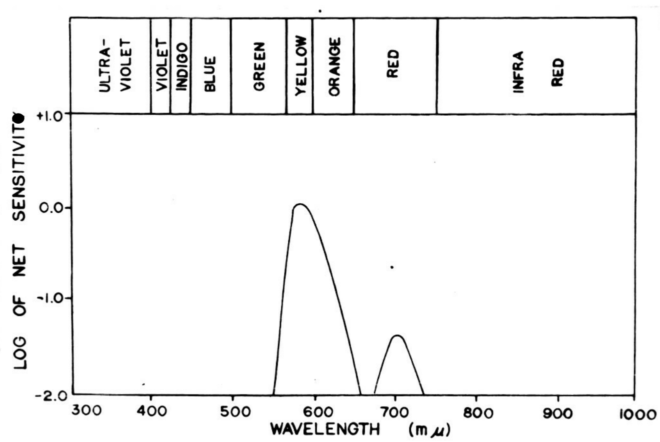
Type of Target: Terrain Types at Pisgah Crater and Masonite Color Panels

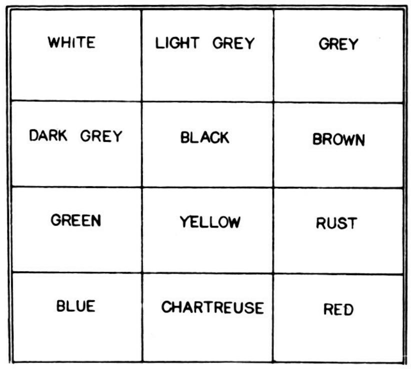
Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: **10** units, or 5175 °K




TARGET ARRAY

Film: Panchromatic Filter: Wratten 90 Sun Angle: Low

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 117 | 100 | 100 | 104 |
| Light Grey | 54 | 86 | 83 | 87 | 86 | 91 |
| Medium Grey | 36 | 72 | 70 | 78 | 72 | 82 |
| Dark Grey | 21 | 54 | 59 | 66 | 54 | 71 |
| Brown | 7 | 25 | 49 | 42 | 25 | 48 |
| Green | 12 | 63 | 53 | 54 | 63 | 59 |
| Yellow | 69 | 100 | 94 | 92 | 100 | 96 |
| Rust | 25 | 79 | 62 | 70 | 79 | 75 |
| Blue | 3 | 36 | 46 | 24 | 36 | 30 |
| Chartreuse | 13 | 72 | 53 | 56 | 72 | 61 |
| Red | 13 | 97 | 53 | 56 | 97 | 61 |
| Black | 0 | 0 | 44 | 0 | 0 | 7 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.221* | 0.100* | 0.085* | 0.035 |
| K-S Statistic | 0.072 | 0.049 | 0.050 | 0.049 |
| Coefficient of Correlation | 0.70 | | 0.88 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: Cary (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Yellow | 100 | 100 | 107 | 100 | 100 | 100 |
| Red | 11 | 96 | 49 | 52 | 96 | 56 |
| Rust | 31 | 68 | 62 | 75 | 68 | 77 |
| Chartreuse | 14 | 56 | 51 | 57 | 56 | 61 |
| Green | 13 | 42 | 51 | 56 | 42 | 59 |
| Blue | 0 | 0 | 47 | 0 | 0 | 7 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.142* | 0.117* | 0.129* | 0.091* |
| K-S Statistic | 0.105 | 0.072 | 0.074 | 0.072 |
| Coefficient of Correlation | 0.63 | | 0.84 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 106 | 100 | 100 | 88 |
| Fine Black Cinders | -1 | 16 | 16 | 0 | 16 | -3 |
| Fine Red Cinders | 9 | 13 | 25 | 48 | 13 | 40 |
| Coarse Black Cinders | 6 | 5 | 23 | 39 | 5 | 32 |
| Coarse Red Cinders | 20 | 67 | 35 | 65 | 67 | 56 |
| Smooth Lava | 7 | 45 | 24 | 42 | 45 | 35 |
| Rough Lava | 0 | 0 | 17 | 0 | 0 | -3 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.734* | 0.144* | 0.170* | 0.091* |
| K-S Statistic | 0.114 | 0.087 | 0.079 | 0.085 |
| Coefficient of Correlation | 0.85 | | 0.86 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 110 | 100 | 100 | 86 |
| Fine Black Cinders | 2 | 16 | 17 | 15 | 16 | 3 |
| Fine Red Cinders | 6 | 5 | 21 | 39 | 5 | 26 |
| Coarse Black Cinders | 25 | 67 | 39 | 70 | 67 | 56 |
| Coarse Red Cinders | 9 | 13 | 24 | 48 | 13 | 35 |
| Desert Pavement | 23 | 48 | 37 | 68 | 48 | 55 |
| Smooth Lava | 15 | 45 | 30 | 59 | 45 | 46 |
| Rough Lava | 0 | 0 | 16 | 0 | 0 | -12 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.633* | 0.150* | 0.262* | 0.080* |
| K-S Statistic | 0.101 | 0.079 | 0.068 | 0.076 |
| Coefficient of Correlation | 0.88 | | 0.90 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

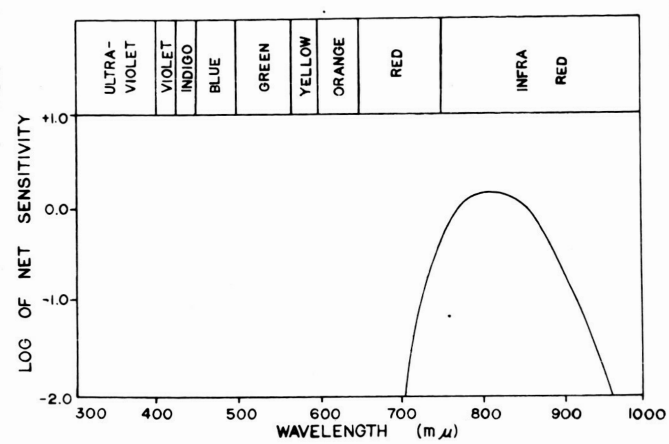
**Type of Target:** Terrain Types at Pisgah Crater and Masonite Color Panels

**Camera Station:** Cessna 180 Aircraft

**Distance from Target Array:** 3,000 feet vertically above

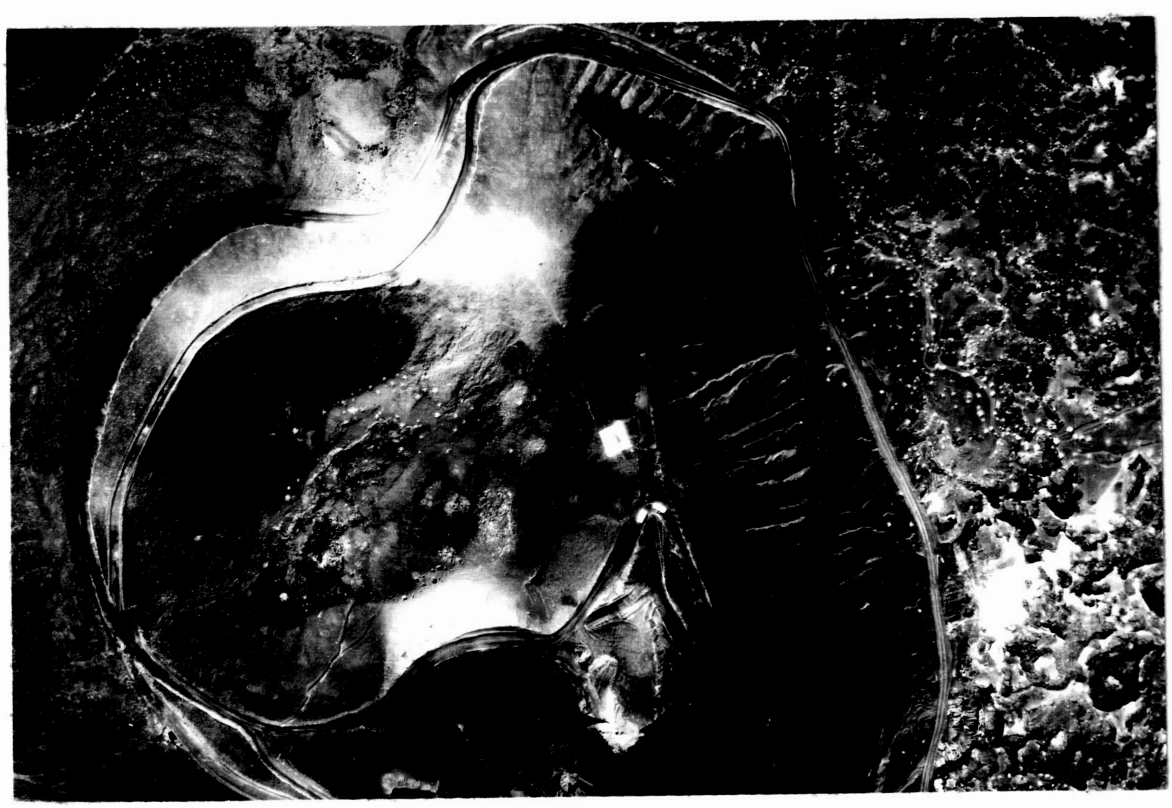
**Camera Used:** K-17 aerial camera with focal length of 12 inches

**Color Temperature Reading of Daylight Sky:** 10 units, or 5175 °K




| | | |
|---|---|---|
| WHITE | LIGHT GREY | GREY |
| DARK GREY | BLACK | BROWN |
| GREEN | YELLOW | RUST |
| BLUE | CHARTREUSE | RED |

TARGET ARRAY



Film: Infrared        Filter: Wratten 89B        Sun Angle: Low

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Infrared, Wratten 89B

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 98 | 100 | 100 | 72 |
| Light Grey | 49 | 84 | 54 | 85 | 84 | 58 |
| Medium Grey | 31 | 67 | 39 | 75 | 67 | 49 |
| Dark Grey | 17 | 43 | 27 | 62 | 43 | 38 |
| Brown | 7 | 20 | 18 | 42 | 20 | 21 |
| Green | 28 | 28 | 36 | 72 | 28 | 47 |
| Yellow | 77 | 99 | 78 | 94 | 99 | 67 |
| Rust | 33 | 38 | 40 | 76 | 38 | 50 |
| Blue | 17 | 7 | 27 | 62 | 7 | 38 |
| Chartreuse | 28 | 34 | 36 | 72 | 34 | 47 |
| Red | 67 | 15 | 70 | 91 | 15 | 64 |
| Black | 0 | 0 | 12 | 0 | 0 | -16 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.244* | 0.061* | 0.362* | 0.107* |
| K-S Statistic | 0.064 | 0.059 | 0.047 | 0.057 |
| Coefficient of Correlation | 0.75 | | 0.68 | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Infrared, Wratten 89B

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 110 | 100 | 100 | 102 |
| Fine Black Cinders | -3 | 51 | 47 | -24 | 51 | 21 |
| Fine Red Cinders | 14 | 72 | 57 | 57 | 72 | 74 |
| Coarse Black Cinders | 3 | 34 | 51 | 24 | 34 | 52 |
| Coarse Red Cinders | 22 | 95 | 62 | 67 | 95 | 81 |
| Smooth Lava | 6 | 76 | 52 | 39 | 76 | 62 |
| Rough Lava | 0 | 0 | 49 | 0 | 0 | 36 |
| Computed K-S Maximum | 1.932* | 0.143* | | 0.529* | 0.071* | |
| K-S Statistic | 0.112 | 0.066 | | 0.077 | 0.066 | |
| Coefficient of Correlation | | 0.63 | | | 0.78 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Infrared, Wratten 89B

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 117 | 100 | 100 | 105 |
| Fine Black Cinders | -1 | 51 | 46 | 0 | 51 | 22 |
| Fine Red Cinders | 5 | 34 | 50 | 35 | 34 | 51 |
| Coarse Black Cinders | 38 | 95 | 73 | 79 | 95 | 88 |
| Coarse Red Cinders | 15 | 72 | 57 | 59 | 72 | 71 |
| Desert Pavement | 24 | 82 | 63 | 69 | 82 | 79 |
| Smooth Lava | 15 | 76 | 57 | 59 | 76 | 71 |
| Rough Lava | 0 | 0 | 46 | 0 | 0 | 22 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 1.586* | 0.112* | 0.273* | 0.044 |
| K-S Statistic | 0.097 | 0.060 | 0.068 | 0.060 |
| Coefficient of Correlation | 0.69 | | 0.89 | |

*Significant at a 95% Confidence Level

MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

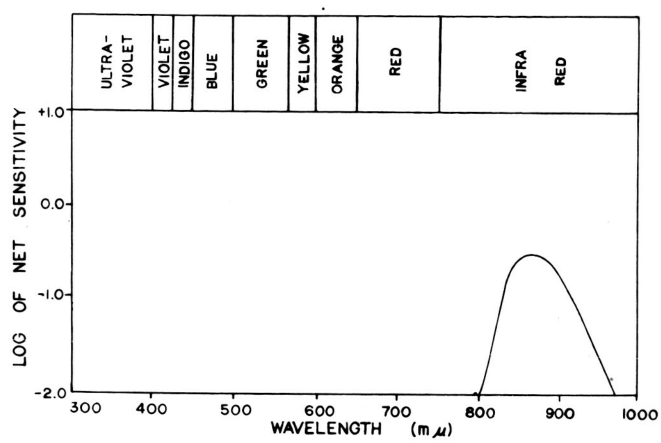
Type of Target: Terrain Types at Pisgah Crater and Masonite Color Panels

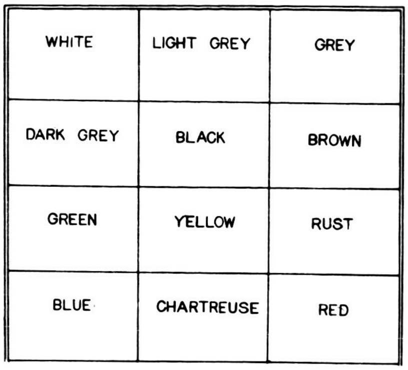
Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

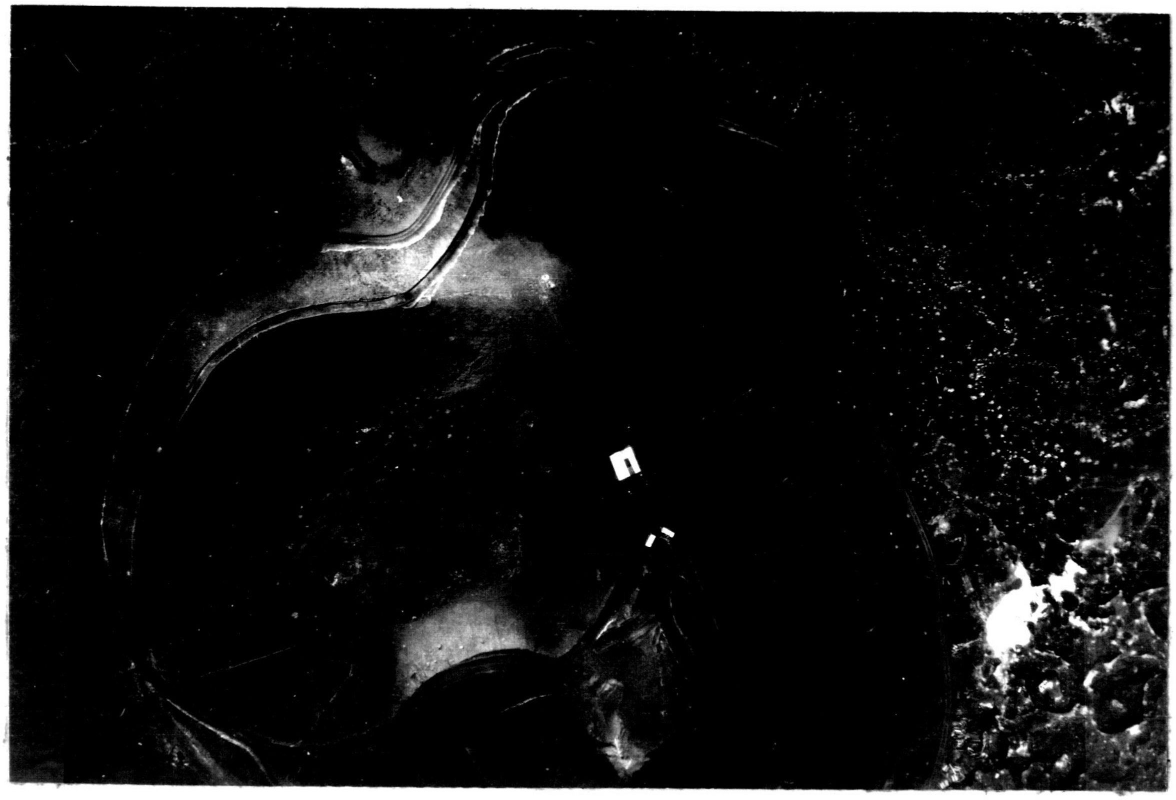
Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




TARGET ARRAY



Film: Infrared Filter: Wratten 87C Sun Angle: Low

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Infrared, Wratten 87C

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Color Panels

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Color Panel | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| White | 100 | 100 | 73 | 100 | 100 | 55 |
| Light Grey | 47 | 76 | 41 | 84 | 76 | 45 |
| Medium Grey | 30 | 62 | 31 | 74 | 62 | 39 |
| Dark Grey | 16 | 43 | 22 | 60 | 43 | 30 |
| Brown | 7 | 7 | 17 | 42 | 7 | 19 |
| Green | 45 | 33 | 40 | 83 | 33 | 44 |
| Yellow | 77 | 52 | 59 | 94 | 52 | 52 |
| Rust | 32 | 7 | 32 | 75 | 7 | 40 |
| Blue | 25 | 41 | 28 | 70 | 41 | 36 |
| Chartreuse | 33 | 23 | 33 | 76 | 23 | 40 |
| Red | 69 | -1 | 55 | 92 | -1 | 50 |
| Black | 0 | 0 | 12 | 0 | 0 | -8 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.156* | 0.097* | 0.479* | 0.098* |
| K-S Statistic | 0.062 | 0.065 | 0.047 | 0.064 |
| Coefficient of Correlation | 0.56 | | 0.54 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

Film-Filter: Infrared, Wratten 87C

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 102 | 100 | 100 | 71 |
| Fine Black Cinders | -3 | 7 | 7 | -24 | 7 | -12 |
| Fine Red Cinders | 14 | 22 | 23 | 57 | 22 | 42 |
| Coarse Black Cinders | 2 | 17 | 12 | 15 | 17 | 14 |
| Coarse Red Cinders | 21 | 37 | 29 | 66 | 37 | 48 |
| Smooth Lava | 6 | 15 | 15 | 39 | 15 | 30 |
| Rough Lava | 0 | 0 | 10 | 0 | 0 | 4 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.397* | 0.051 | 0.184* | 0.131* |
| K-S Statistic | 0.113 | 0.097 | 0.078 | 0.091 |
| Coefficient of Correlation | 0.99 | | 0.84 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Pisgah Crater

FilmpFilter: Infrared, Wratten 87C

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Fine White Soil | 100 | 100 | 98 | 100 | 100 | 56 |
| Fine Black Cinders | -3 | 7 | 2 | -24 | 7 | -12 |
| Fine Red Cinders | 6 | 17 | 10 | 39 | 17 | 22 |
| Coarse Black Cinders | 36 | 37 | 38 | 78 | 37 | 44 |
| Coarse Red Cinders | 15 | 22 | 19 | 59 | 22 | 33 |
| Desert Pavement | 26 | 20 | 29 | 71 | 20 | 40 |
| Smooth Lava | 15 | 15 | 19 | 59 | 15 | 33 |
| Rough Lava | 0 | 0 | 5 | 0 | 0 | 1 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.139* | 0.050 | 0.380* | 0.181* |
| K-S Statistic | 0.096 | 0.092 | 0.066 | 0.087 |
| Coefficient of Correlation | 0.99 | | 0.73 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 12

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 101 | 100 | 100 | 99 |
| Smooth Lava | 6 | 36 | 20 | 39 | 36 | 38 |
| Rough Lava | 0 | 0 | 15 | 0 | 0 | -1 |
| Computed K-S Maximum | 0.283* | | 0.110 | 0.021 | | 0.008 |
| K-S Statistic | 0.132 | | 0.117 | 0.115 | | 0.116 |
| Coefficient of Correlation | | 0.95 | | | 1.00 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 12

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 107 | 100 | 100 | 93 |
| Alluvium Soil | 11 | 36 | 25 | 52 | 36 | 46 |
| Smooth Lava | 58 | 79 | 68 | 88 | 79 | 81 |
| Rough Lava | 0 | 0 | 14 | 0 | 0 | -5 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.272* | 0.067 | 0.105* | 0.032 |
| K-S Statistic | 0.105 | 0.093 | 0.088 | 0.091 |
| Coefficient of Correlation | 0.96 | | 0.98 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 47B

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 89 | 100 | 100 | 64 |
| Alluvium Soil | 17 | 0 | 2 | 54 | 0 | 27 |
| Smooth Lava | 60 | 31 | 49 | 89 | 31 | 55 |
| Rough Lava | 6 | 0 | -9 | 0 | 0 | -15 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.238* | 0.076 | 0.461* | 0.224* |
| K-S Statistic | 0.104 | 0.111 | 0.087 | 0.107 |
| Coefficient of Correlation | 0.96 | | 0.75 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

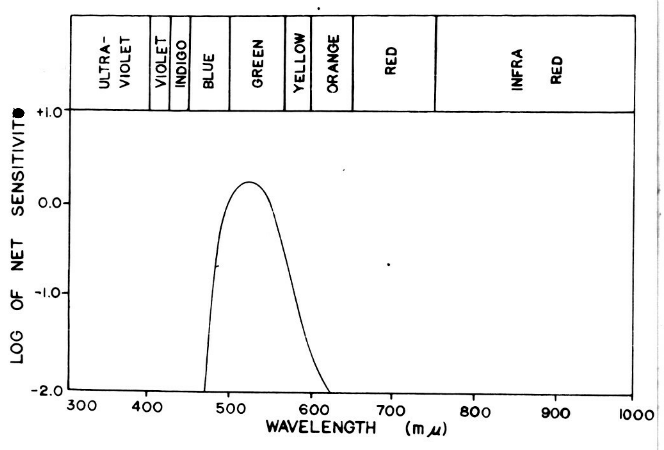
Type of Target: Terrain Types at Lavic Lake

Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K




Film: Panchromatic Filter: Wratten 61 Sun Angle: Low

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 101 | 100 | 100 | 95 |
| Smooth Lava | 8 | 29 | 18 | 45 | 29 | 40 |
| Rough Lava | 0 | 0 | 10 | 0 | 0 | -6 |
| Computed K-S Maximum | 0.194* | | 0.081 | 0.111 | | 0.042 |
| K-S Statistic | 0.131 | | 0.120 | 0.113 | | 0.115 |
| Coefficient of Correlation | | 0.98 | | | 0.98 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 61

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 106 | 100 | 100 | 90 |
| Alluvium Soil | 10 | 29 | 21 | 50 | 29 | 42 |
| Smooth Lava | 57 | 75 | 65 | 88 | 75 | 79 |
| Rough Lava | 0 | 0 | 11 | 0 | 0 | -7 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.222* | 0.056 | 0.142* | 0.044 |
| K-S Statistic | 0.105 | 0.095 | 0.088 | 0.092 |
| Coefficient of Correlation | 0.97 | | 0.97 | |

*Significant at a 95% Confidence Level

MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

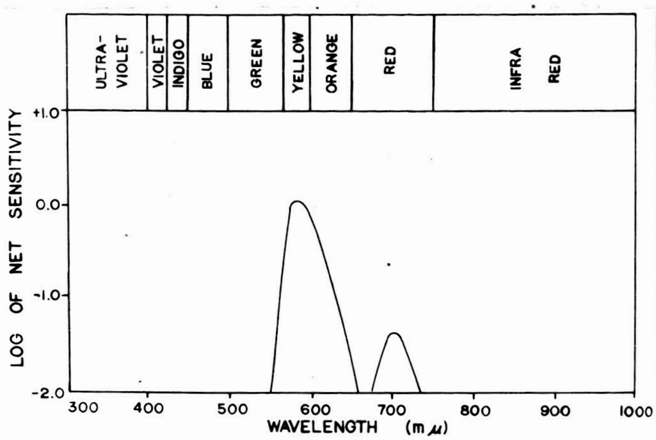
Type of Target: Terrain Types at Lavic Lake

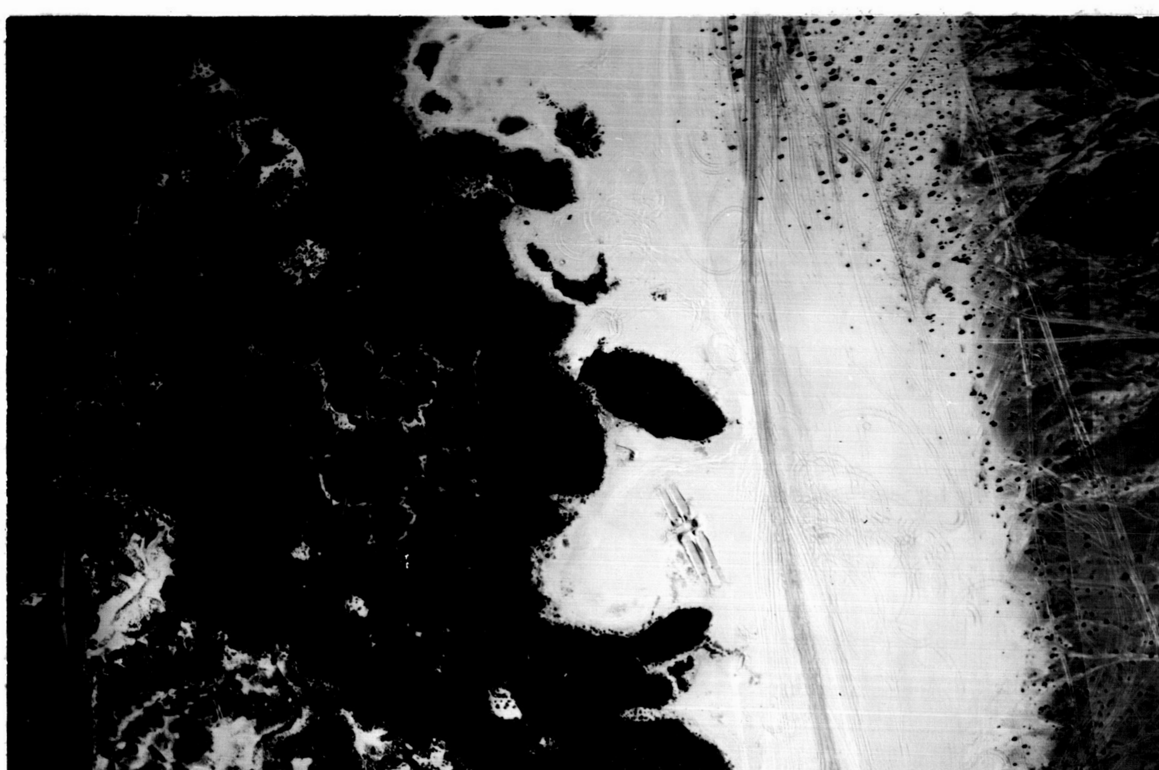
Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K



Film: Panchromatic    Filter: Wratten 90    Sun Angle: Low

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 100 | 100 | 100 | 94 |
| Smooth Lava | 6 | 17 | 11 | 39 | 17 | 31 |
| Rough Lava | 0 | 0 | 5 | 0 | 0 | -9 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.104 | 0.047 | 0.158* | 0.065 |
| K-S Statistic | 0.132 | 0.126 | 0.115 | 0.117 |
| Coefficient of Correlation | 0.99 | | 0.97 | |

*Significant at a 95% Confidence Level

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Panchromatic, Wratten 90

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 96 | 100 | 100 | 76 |
| Alluvium Soil | 11 | 17 | 12 | 52 | 17 | 35 |
| Smooth Lava | 59 | 50 | 57 | 89 | 50 | 66 |
| Rough Lava | 0 | 0 | 1 | 0 | 0 | -10 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.035 | 0.023 | 0.306* | 0.126* |
| K-S Statistic | 0.104 | 0.105 | 0.088 | 0.099 |
| Coefficient of Correlation | 0.99 | | 0.89 | |

*Significant at a 95% Confidence Level

# MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

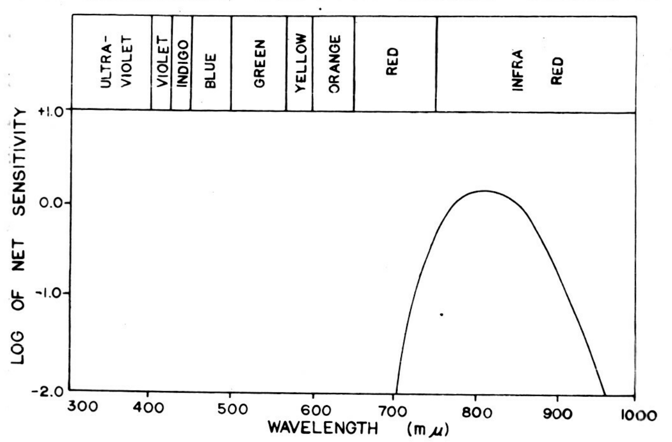
Type of Target: Terrain Types at Lavic Lake

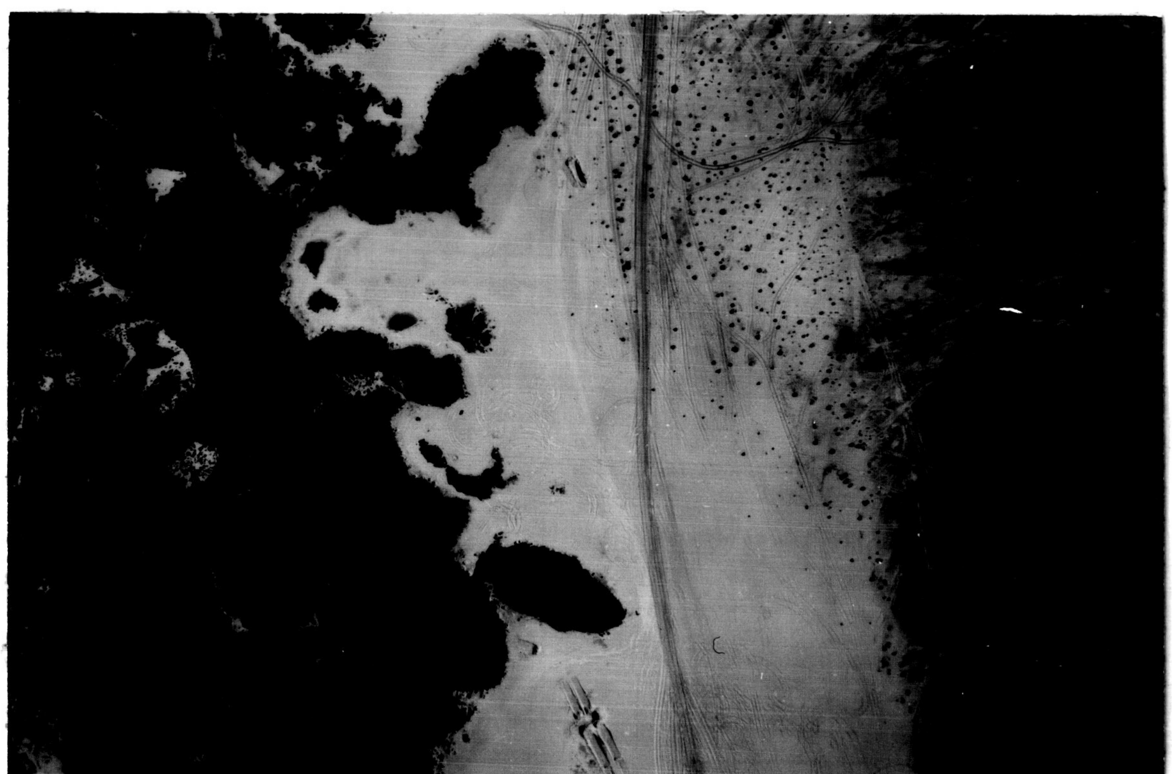
Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175 °K



Film: Infrared

Filter: Wratten 89B

Sun Angle: Low

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Infrared, Wratten 89B

Sun Angle: Low

Spectrophotometer: General Electric (Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 101 | 100 | 100 | 101 |
| Smooth Lava | 6 | 41 | 22 | 39 | 41 | 40 |
| Rough Lava | 0 | 0 | 17 | 0 | 0 | 1 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.330* | 0.124* | 0.015 | 0.006 |
| K-S Statistic | 0.132 | 0.114 | 0.115 | 0.114 |
| Coefficient of Correlation | 0.93 | | 1.00 | |

*Significant at a 95% Confidence Level

# PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Infrared, Wratten 89B

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 109 | 100 | 100 | 97 |
| Alluvium Soil | 9 | 41 | 27 | 48 | 41 | 45 |
| Smooth Lava | 59 | 85 | 72 | 89 | 85 | 86 |
| Rough Lava | 0 | 0 | 18 | 0 | 0 | -2 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.345* | 0.082 | 0.043 | 0.012 |
| K-S Statistic | 0.105 | 0.090 | 0.088 | 0.090 |
| Coefficient of Correlation | 0.93 | | 1.00 | |

*Significant at a 95% Confidence Level

## MULTISPECTRAL PHOTOGRAPHIC EXPERIMENT

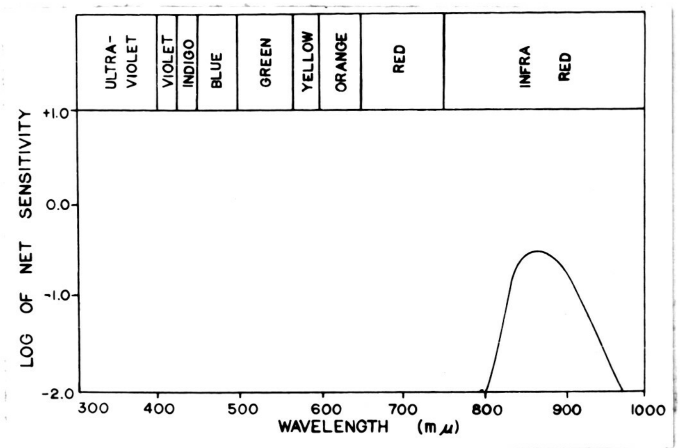
Type of Target: Terrain Types at Lavic Lake

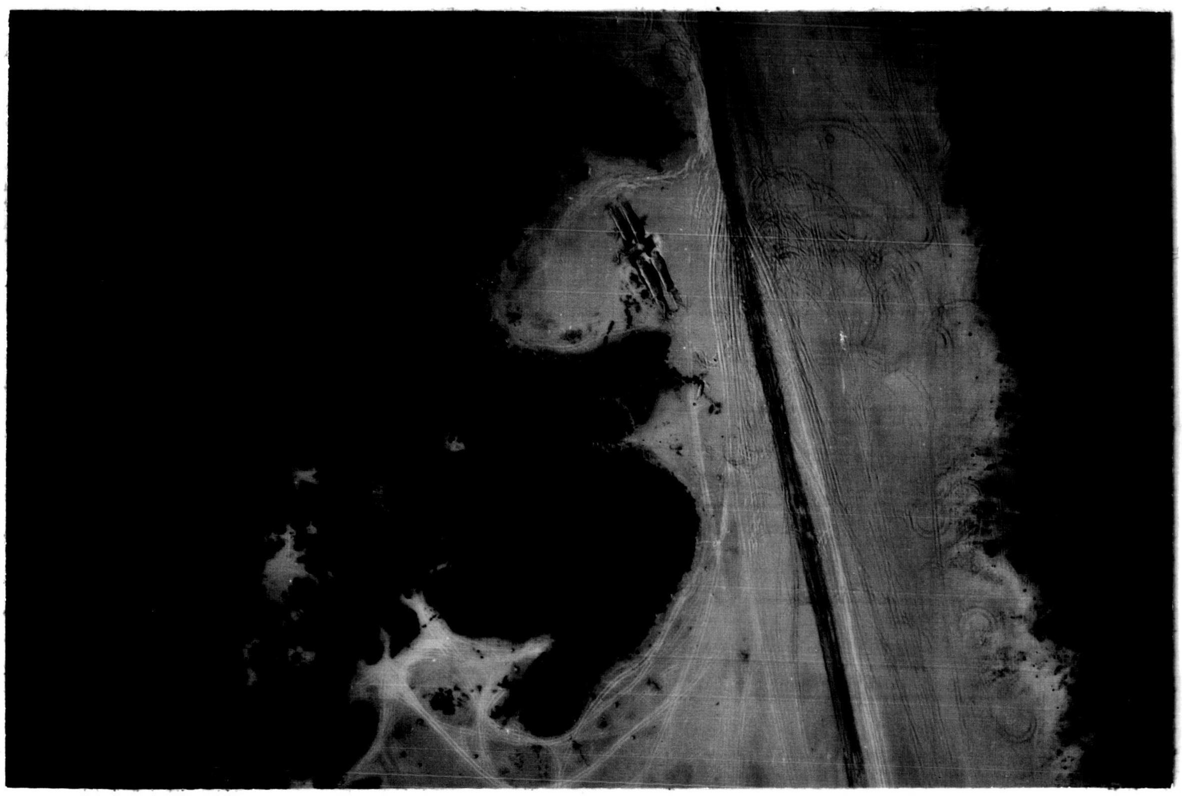
Camera Station: Cessna 180 Aircraft

Distance from Target Array: 3,000 feet vertically above

Camera Used: K-17 aerial camera with focal length of 12 inches

Color Temperature Reading of Daylight Sky: 10 units, or 5175°K



Film: Infrared Filter: Wratten 87C Sun Angle: Low

## PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Infrared, Wratten 87C

Sun Angle: Low

Spectrophotometer: (General Electric Laboratory)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 99 | 100 | 100 | 85 |
| Smooth Lava | 6 | -18 | -5 | 39 | -18 | 19 |
| Rough Lava | 0 | 0 | -12 | 0 | 0 | -23 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.226* | 0.103 | 0.410* | 0.179* |
| K-S Statistic | 0.132 | 0.126 | 0.115 | 0.120 |
| Coefficient of Correlation | 0.98 | | 0.86 | |

*Significant at a 95% Confidence Level

PREDICTED VS. ACTUAL TONE VALUES

Test Area: Lavic Lake

Film-Filter: Infrared, Wratten 87C

Sun Angle: Low

Spectrophotometer: U.S.A. E.R.D.L. (Portable)

Target: Terrain Types

| | Prediction Function | | | | | |
|---|---|---|---|---|---|---|
| | Linear | | | Logarithmic | | |
| Terrain Type | Predicted | Actual | Calculated | Predicted | Actual | Calculated |
| Lake Bed Soil | 100 | 100 | 81 | 100 | 100 | 54 |
| Alluvium Soil | 9 | -18 | -10 | 48 | -18 | 15 |
| Smooth Lava | 61 | 12 | 42 | 89 | 12 | 46 |
| Rough Lava | 0 | 0 | 19 | 0 | 0 | -21 |

| | Linear | | Logarithmic | |
|---|---|---|---|---|
| Computed K-S Maximum | 0.447* | 0.125* | 0.603* | 0.339* |
| K-S Statistic | 0.104 | 0.110 | 0.088 | 0.117 |
| Coefficient of Correlation | 0.89 | | 0.65 | |

*Significant at a 95% Confidence Level